AQUATIC MICROSCOPY

FOR BEGINNERS

OR

Common Objects from the Ponds and Ditches

BY

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PREFACE

The beginner in the use of the microscope naturally turns to the ponds and the slow streams for his objects of study, as he has heard that the waters abound in interesting plants and animals invisible to the unaided vision: but how can he bring the pond to the instrument, or take the microscope to the pond? The youthful student alone in even the most favorable country place, wanders and blunders and wastes his time, because he has no guide. "Aquatic Microscopy," elementary, simple, easily comprehended, is intended to be that guide, and to lead the novice in the most direct way along the smoothest paths.

The book contains little or no technical language nor strictly scientific descriptions. The author had in mind the needs of the novice and his limitations, and wrote accordingly. The book tries to be helpful, and to be so in the simplest and most direct way. Uncomplicated Analytical Tables or Keys lead to every subject, and similar Keys subdivide those topics so that even he that runs may read.

It says little about development and life-history. These subjects are left to the strictly scientific treatises and monographs intended for the advanced investigator.

With few exceptions, notably certain western forms, every object mentioned in the book was taken by the author from a single pond in central New Jersey. Plants and animals of the same kind abound in similar places in other localities. There is no scarcity. All that is needed is a microscope, a little energy, a tin dipper and a bottle.

Teachers, leaders in Nature-Study, and microscopical opticians should welcome the book as a simple, helpful, earnest assistant in their work.

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AQUATIC MICROSCOPY FOR BEGINNERS

INTRODUCTION

To the beginner in the use of the microscope, to the beginner in the study of any department of natural history, the name of the specimen found is of the first importance. It is the key that opens the door to further knowledge, and until it is obtained the observer is helpless; the books are closed to him, all conference with others in reference to the object or specimen is impossible, and, in many, a budding interest that might otherwise bloom and bear fruit, is crushed and destroyed. The first question asked is always, "What is it?" and unless the questioner has a kind and experienced friend to whom he can take the specimen, or a book of common objects from which the names of ordinary natural-history materials can be ascertained, the question is too often unanswered, and the beginner soon loses his relish for the unknown in Nature, because to him it always remains the unknowable.

In England numerous little handbooks in all departments of natural science are within the reach of every reader, even the least wealthy. They are written in an attractive style, they are usually accurate as far as they go, and they aim to describe the common objects to be found in the green lanes and in the woods, in the waters of the ponds and streams, and of the shallow bays and inlets of the sea, so that any one with the least inclination toward the study of the teeming world of animal and vegetable life can, at slight expenditure

of time, labor, and money, learn the names, and some of the structure of the common things that surround him.

Such books, if correct and helpful, are worthy of all praise. That there is a desire for such, even in this fair land of ours, is evident by their importation, and their appearance on the counters of the booksellers and on the shelves of the public libraries. But they are seldom adapted to our needs. Their descriptions are commonly too general and diffuse; their writers pay more attention to literary style than to the imparting of definite information, and the text too often bears internal evidence of having been made to suit certain pictures owned, and necessary to be utilized by the publisher.

That similar and better books on the life in American fields and streams, and on American sea-shores, are so few is much to be regretted. There should be small and untechnical handbooks adapted to "all capacities, even the meanest," as our forefathers used to put it, and in all departments of animal and vegetable life; books in which the beginner could learn the names of things.

"I do beseech you, what is your name?" is the oft-repeated question, not only by the beginner in the use of the microscope, but by the more advanced student in other departments of science. "Naming things," says Prof. Henry Van Dyke, "is one of the oldest and simplest of human pastimes. Children play at it with their dolls and toy animals. In fact, it was the first game ever played on earth, for the Creator who planted the garden eastward in Eden, knew well what would please the childish heart of man when He brought all the new-made creatures to Adam 'to see what he would call them.'"

But there is so much for our learned scientists to do in our comparatively unexplored land, that they may have no time to stoop and lend a hand to those that would like to enter a little way into the attractive world of science, from which faint but pleasing rumors occasionally drift. All these learned men are courteous and communicative when personally approached, but what boy or other young person with an inclination toward "bugs and things" would be

willing, or indeed would know how to seek aid from these celebrated investigators? If the student is alone in a country place where Nature smiles her sweetest, but where there are no libraries and no human being to consult, except perhaps "the minister," how then shall he learn the name of the flower, the stone, or the bird that attracts his attention? "The minister" is usually poor authority on such subjects, and the boy, after wondering and investigating in an awkward and boyish fashion, soon gives it up, when he might have become a lover of Nature, and perhaps a lover of something even better than Nature.

Dr. Joseph Leidy, one of the most illustrious naturalists and microscopists of this country, voices this sentiment in his magnificent monograph on the "Fresh-water Rhizopods of North America" (Chap. IV), when he says that he considers it worth his while to embrace the opportunity afforded by the publication of his book, to inform students that microscopical observations, such as form the basis of that work, do not require elaborate and high-priced instruments, nor high-power and expensive magnifying lenses (objectives), a one-fourth or a one-fifth inch objective being sufficient, with only an occasional call for a lens of greater magnifying power.

"'Going fishing?' How often the question has been asked by acquaintances as they have met me, with rod and basket, on an excursion after materials for microscopic study. Yes! has been the invariable answer . . . and now, behold, I offer them the results of that fishing. No fish for the stomach, but as the old French microscopist Joblot observed, 'some of the most remarkable fishes that have ever been seen.'"

In the course of the preparation of the book, its famous author tells us that he had ever in mind his pupils at the University of Pennsylvania, and of Swarthmore College, especially the boys and girls of the College. "I shall be glad," he says, "if it serve as an additional aid to their studies."

A private letter from an eminent professor of histology in one of our prominent universities, is in touch with this thought when he says: "My interest in microscopical work began as

a schoolboy, and . . . I believe that if we could only cultivate that boyish love of the curious and the beautiful carefully enough, and then guide it aright, we could do a world of good to biological science, and save some of our young men from hours of ennui which lead to hurtful associations and habits, by having their leisure hours occupied by a profitable and healthful pursuit of information. This is one of the English ideas that I wish we could copy in this country. How many men are to be found in England who have hobbies in geology, botany or biology, and do successful work in them, too, who are actually engaged in business during most of their time."

Many a child born with a love for Nature has not had sufficient will-power to resist the will-power of older persons but has been ridiculed out of his liking for "bugs and things." There are few boys or even men like Thomas Edwards, the Scottish naturalist, who persisted, notwithstanding the weight of the maternal hand, and the sting of the maternal vocabulary. And what a pathetic cry was that of Carlyle in his old age: "Would to God some one had taught me in my youth the names of the grasses!"

But the possessor of a microscope looks at the two or three mounted objects supplied by the dealer, and then wonders if those are all, if those are the only foundation for the charming stories that he has heard of the charming things to be seen with the microscope.

"Will you tell me where I can find a book that will help me to know microscopic plants from microscopic animals, and teach me how I can best collect them," is a question that has often, in some shape, been asked of the writer, and has as often remained unanswered, for there is no book on common American microscopic objects. It is only possible to direct the questioner to the ditches and the ponds, and to wish him a success that is almost hopeless. In any event, the beginner naturally, and almost instinctively, goes first to the water for his microscopic objects, probably because he has heard so much about the "animalcules" there. His first examination bewilders him; there is so much life and motion and color;

there are so many strange forms; but where shall he turn for help?

Since our illustrious scientists have not offered to aid him, the writer, who is himself only a beginner, and who makes not the slightest pretension, has sympathized with the inquirers whom he has been compelled to turn away unsatisfied, when they have come for printed help in their microscopical work, and this little book is the result. Its only aim is to help the observer to ascertain the names, and a little of the structure of a few of the common microscopic creatures, both animal and vegetable, with which the fresh waters of the land are filled, and it tries to do so in the simplest and most direct way, leaping scientific hedges and trampling on scientific classification in a manner that will dismay the learned botanist and zoologist.

But the botanist and zoologist has weighty books that delight his soul, so why should not the beginner with a microscope have a book to help him, if to nothing more than to the names of the commonest aquatic objects, and, it is hoped, to delight him by smoothing the path that leads to them? The writer will not be greatly troubled if the learned botanists and zoologists do not like this little book, provided the beginners in the use of the microscope approve of it and find it helpful.

It relates exclusively to aquatic objects. One reason for this has already been mentioned. Another and more potent is, that even the beginner knows, in a general way, what he is looking at when he magnifies the common objects of the land, but the microscopic creatures from the water are so truly microscopic, the observer must so often go fishing on faith, and know the contents of his net only by faith and imagination, until he can examine his collection drop by drop with the microscope, that he is lost at the start unless he has a book to help him, as it is hoped that this one will do.

The owner of a microscope should never take a walk in the country without one or two wide-mouthed bottles in his pocket. Empty morphia bottles, to be had from any drug-

gist, are convenient for small collections; for greater quantities an empty quinine bottle, and for still larger gatherings of aquatic plants the ordinary glass fruit-jar is admirable, if a string be added for a handle. No bottle should be entirely filled and corked, or all animal life will be animal death before the microscope is reached. Leave a large space for air between the cork and the water.

But is it necessary to say that the following pages do not contain notices of everything to be found in the ponds and the ditches? The reader will capture many objects that he will not find there described. It is not possible that this should be otherwise. The waters are crowded with life; it is only the commonest objects and those most frequently found, that a little book of this kind can attempt to include.

The descriptions of those few have been made as plain as possible. The writer has seldom allowed himself to "drop into poetry," although often sorely tempted. The Keys, or Analytical Tables, so freely scattered through the pages have been purposely made as artificial as possible. They use the most conspicuous external characters, with little regard to scientific classification, and with regard to but one result only—to help the reader to find the name, at least the generic name, of his specimen. If this is accomplished the book will have attained its purpose. The method of using the Keys is explained on another page.

There is literally no end to the objects worth examining with the microscope. Even a pocket-lens reveals new and wondrous aspects in the most familiar things. An old and leathery lichen from a stump becomes a charming picture and a living one, for its hills and hollows and winding valleys are the homes and the hiding places of innumerable little creatures that the pocket-lens brings to view. The furrowed and weather-worn bark of any tree has countless points of interest and of charm.

Neither need there be any scarcity of material at any season of the year. In the spring and the summer the only trouble is to find the time to examine even a small portion

of all the wondrous and beautiful things that Nature then offers.

In midwinter, life and beauty are almost as abundant, if less conspicuous. The dust swept by a feather from the wall of a dark cellar may bring to light minute creatures not to be obtained elsewhere. There is no end to the objects, there is no end to the unlikely places that will reward a little search, and there is no end to the telling, unless it be an abrupt end.

Although the reader may never be at a loss for the employment of his pocket-lens, he may at first feel that his compound microscope will never afford him either amusement or instruction. How glaring and how laughable will such a mistake appear after six months' use of the instrument!

When recommending a friend to purchase a microscope, he will speak of that conclusion as an amusing episode of his life. Yet the beginner, especially if alone, or if without a friend to suggest, or an experienced microscopist to instruct, must necessarily be somewhat at a loss as to how to make a start. I know of no remedy for this unpleasant feeling except experiment. Take the first small object that may be convenient, place it on a glass slip, and examine it with a low-power objective; add a drop of water, cover it with a thin-glass square or circle, and note the change in its appearance.

But do not imitate the man that returned his microscope to the manufacturer because, as he said, it would not show the crystals in sugar. After much questioning it was discovered that he had placed a lump of loaf-sugar on the stage, expecting that the crystals would at once become conspicuous. And do not imitate the other man that put on his stage a piece of anthracite direct from the bin, expecting it to reveal without any previous preparation, its vegetable nature and its fern fragments or impressions. A lump of sugar or of coal is a dark object when an attempt is made to throw light through it by the microscope-mirror, yet both are beautiful and interesting when viewed as opaque objects, with the light reflected on them from the concave mirror swung above the stage, or from the focused bulls-eye condenser. To see the sugar

crystals, or the structure of coal, demands careful and skilful preliminary preparation of the materials. The coal must be sliced and ground down until it becomes transparent, or at least translucent, an operation that needs an expert to accomplish. Sugar crystals, when they have been prepared for the purpose, may be seen by any one.

The smaller the object the better it usually is for microscopical examination. The actual field of even a low-power objective is much smaller, and consequently includes much less of the object, than the beginner would imagine. Make the experiment by placing a piece of hair a quarter of an inch long under the one-inch objective. Both ends of the hair cannot be seen in the field at the same time. The stage must be moved for what appears to be a long distance before the end is brought into view. With the one-fifth inch objective the field is still smaller; the higher the power the smaller the field.

This matter of the actual size of the field of view is misleading. The circular lighted area (the field) seen when the microscope is set up, and the mirror is reflecting the light upward through the body-tube, appears to be from six to eight inches in diameter, the appearance varying somewhat with eyepieces of different magnifying power; the higher that power, with ordinary oculars, the smaller the field.

The object to be examined should be as thin as possible, so that the light may pass through it, unless it is to be viewed as an opaque object, with the light thrown on it from the concave mirror swung above the stage. In that case the thickness makes little difference, if the observer will remember that the microscope is for the study of small things. In opaque objects only the surface can be examined, an important and often beautiful part, but in transparent substances the internal structure may be studied.

The reader will soon become so interested in some special class of Nature's handiwork, that he will leave all the others and devote himself to that one. No single student can expect or hope to cultivate all departments of microscopical science.

The field is too vast and life is too short. Most heartily would I recommend the beginner in the use of the microscope to spend several years if necessary, in taking short excursions into as many different microscopical departments as possible, and then intelligently to select some one scientific field, of which there are many, and make its cultivation the work and the recreation of his leisure hours. The work will soon become recreation, and the recreation will soon result in increased knowledge, not only to the student-worker, but perhaps to the scientific world at large.

In the cultivation of a single field to the exclusion of all others, he may gradually fail to see beauty or interest in the field of his neighbor just over the fence. Indeed, he may go so far as to accuse that innocent neighbor of scattering tares and thistles through the openings in the dividing partition, because some of the specialist's Diatoms (Chap. III) may have wandered across the line, and temporarily affiliated with his Desmids. And it is not improbable that the neighbor with the Desmids (Chap. III) may be irreverent enough to refer disparagingly to the Diatoms. A diatomist has been heard to say, that he has a single Diatom beautiful enough to be the collar-button of an archangel; while a specialist in another department informed his friends, that he could never study the Infusoria (Chap. V); it would make him insane to watch creatures that so everlastingly wriggle.

Such experiences may perhaps be expected. They are amusing and harmless. Every parent loves his own child better than he loves his neighbor's. My specialty is to me more important than yours. You may have a similar opinion of mine. If we are both happy, "what's the odds?"

There can be no better way to employ one's leisure hours than by scientific work, or even by scientific play. The illustrious Leidy says, in his monograph on the fresh-water Rhizopods of North America: "The study of natural history in the leisure of my life, since I was fourteen years of age, has been to me a constant source of happiness, and my experience of it is such that, independently of its higher merits, I warmly

recommend it as a pastime, than which, I believe, no other can excel it. At the same time, in observing the modes of life of those around me, it has been a matter of increasing regret that so few, so very few people give attention to intellectual pursuits of any kind. In the incessant and necessary struggle for bread, we repeatedly hear the expression that 'man shall not live by bread alone,' and yet it remains unappreciated by the mass of even so-called enlightened humanity. In common with all other animals, the engrossing care of man is food for the stomach, while intellectual food remains unknown, is disregarded or rejected."

Finally, to the beginners in the use of the microscope, for whom this book has been prepared, the author would say as has so often been said, There is no royal road. The mother bird finds and brings the food, but even the youngest nestling opens its own mouth.

CHAPTER I

THE MICROSCOPE AND ITS PARTS

MICROSCOPES are compound or simple: compound when they consist of two or more glasses, one or more being near the object to be examined, and one or more near the eye of the observer; simple when they consist of but one double-convex lens to be held near the object, or of two or more lenses that can be used singly or all at the same time. When thus used in combination, the two or three simple lenses are not only placed close to each other, but close to the object, the combination acting as if it were a single lens, the magnifying power being much greater than that of but one glass and the distance from the object much shorter when in focus.

In the compound microscope the lenses near the eye magnify the image formed by the lower lenses, and that image is inverted and transposed, the upper edge of the object then appearing to be the lower, the right-hand edge the left, and the left-hand the right. In the simple microscope these changes do not take place; and in those forms where two or three lenses are combined, the effect is the same as though one glass of great magnifying power were used. But separate the lenses so that the upper shall magnify the image produced by the lower, and you have a simple form of compound microscope. With the simple microscope we see the object itself; in the compound, we see the enlarged image of the object.

As a simple microscope does not seem to invert and reverse the object, and because the distance between the two is long when the low-power glass is in focus—that is, when the lens is in such a position that the magnified object looks clear and distinct to the eye—it is always used for the examination of a flower, the surface of a piece of bark, a stone, an insect,

or any other specimen of considerable size, or one that is visible to the naked eye, more extended study being reserved for the compound instrument.

A simple microscope, a "pocket-lens" as it is often and preferably called (FIG. 1), is indispensable to every person with a taste for nature studies, and a desire to know somewhat of the beauties hidden from our unaided vision. The simplest glass shows the student unimagined charm in the petal of a flower, in the sand that he walks on, and in the green scum that floats on every summer pool, and perhaps disgusts him until his little lens reveals its purity and its grace.

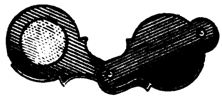


FIG. 1.—A Pocket-lens.

The pocket-lens is always ready for the examination of anything picked up in the fields or the woods; it is small, and is easily carried in the pocket. It may be obtained in a great variety of shapes, so far as the frame that holds the lens is concerned; it may be had with but one glass, or with two or three of various powers to be used alone or combined; it may be bought with a large lens of low power in one end of the frame, and a smaller glass of higher power in the other. But whatever form the reader may select, he should remember that the larger the simple lens the lower, as a rule, will be the magnifying power, and the longer the working-distance, or the space between the glass and the object when the lens is in focus; and the smaller the lens the more convex it will be, the greater power it will have, the shorter will be the working-distance, the less of the object it will show at one view, and consequently the more troublesome will be its use.

The reader is advised to purchase a good pocket-lens with a working-distance, or "focal-length" as it is sometimes rather incorrectly termed, of one or of one and one-half inches. This is all that is really needed for the examination of botanical specimens, and of the thousand-and-one objects that should attract the attention on every summer ramble.

In his "Life and Letters of Charles Darwin," the biographer

says, in reference to the use of the pocket-lens, that Darwin "always had a great liking for the simple microscope, and maintained that nowadays it was too much neglected, and that one ought always to see as much as possible with the simple before taking to the compound microscope. In one of his letters he speaks on this point, and remarks that he always suspects the work of a man who never uses the simple microscope."

The writer personally dislikes the combination pocket-lens formed of two or three separable glasses. If but one lens of the combination is wanted for immediate use, the entire number must be pushed out of the thick and awkward case, the proper one must be selected and separated, for the perverse thing usually comes out of the pocket upside down, and it is desirable that the highest-power glass shall be next to and nearest the object, while those not needed must be turned to one side, making a series of operations that take time, both hands, and considerable patience if you are anxious to examine the specimen. Your companion may have finished the work with the single glass, and may be telling you how the object looks, before your complicated affair is ready to begin, provided you are not wise enough to have avoided the combination pocket-lens. If the whole number of lenses is used at once, the working-distance is usually so short that the observer's head or his hat-brim shuts off most of the light, so that little of the object can be seen, and that little with difficulty. To see at one view so small a portion as these higher-power combinations always show, and to be compelled to pass the lens over so many small portions before any notion of the whole surface can be obtained, is, to say the least, not satisfactory. Unless the observer is familiar with the entire object, and with the relation and the arrangement of all its parts, a low-power pocket-lens is the most seful, and the one to be commended.

The reader perceives that this matter of short focus is important; the usefulness of the pocket-lens to a great extent depends upon it. Reject without hesitation the simple lens

whose focus is so short that it must be held almost in contact with the object.

A "watchmaker's glass," which is sometimes seen on the microscopist's table, is a simple lens mounted in a short tube of horn or of rubber, so arranged that it can be held to the eye by the contraction of the muscles of the cheek and brow, while both hands are used for the manipulating of the object. It may be obtained of various powers and focal lengths, but it is scarcely desirable. The prolonged contraction of the facial muscles necessary to keep it in place is fatiguing, and the vapor continually evaporating from the front of the eye, being confined within the tube, is sure to condense on the lens and obscure the object. Everything a watchmaker's glass will do, a good pocket-lens will do better.

A "Coddington lens" is admirable in many respects. Its magnifying power is usually great, the image it forms is excellent and the field of view good, but the focus is, as a rule, unpleasantly short. This, apart from its cost, is its only objectionable feature. It is named for the man that first brought it to the notice of the opticians, and not as it should have been, after Sir David Brewster, its inventor. It consists of a sphere of glass with a deep groove cut around its equatorial center, and filled with a black cement, which acts as a diaphragm to arrest certain rays of light whose presence and action would be undesirable, as they would interfere with the formation of a clear and sharply outlined image.

The reader may be surprised to learn that there are persons who do not know how to focus a lens. I have seen such persons take the instrument as if they were afraid of it. They extend it toward the object in a hesitating way, move it about irregularly for a few moments, throw back the head, look cross-eyed, and say, "Oh, yes; I see. How beautiful! And how very queer it looks!" I once offered a lady an opera-glass, which she put to her eyes, and never touched the nurled adjustment-wheel that alters the length of the tubes and focuses the lenses on the actors. When she returned it she said, "Thank you. I don't like it; I can see better without it."

To "get the focus," it is not really necessary to close one eye, although that is usually done. If both eyes are open, the one looking through the lens becomes so interested that the other sees nothing; or, if we prefer, we may say that the brain becomes so interested in contemplating the image formed on the retina of the eye examining the magnified object, that it fails to note the retinal impressions of the other. If one eye must be closed, it can be done, after very little practice, without clapping your hand over it. This applies equally well to the use of the compound microscope.

To focus a pocket-lens, hold the object to be examined in the left hand, and, while looking through the lens, raise and lower the glass with the right hand until the magnified object appears clear and distinct, the outlines sharp, without a fringe of color, and the surface rough or smooth, rounded or concave, as it may indistinctly appear to the unaided eye. The focus cannot be obtained without thus experimenting every time the glass is used. A good plan is to place the lens nearer the object than is known to be necessary, but always without allowing the two to come in contact, and then to raise the glass slowly until the image is distinct, when it will be focused.

The compound microscope (FIG. 2) consists of the stand, the eye-piece, and the objective, although the word, as commonly used, refers to the entire combination of brass, with or without the magnifying glasses. Without the objective the microscope is only the "stand," and is practically useless. The stand alone generally includes the tube or microscope-body; the eye-piece, formed of two lenses one at each of the opposite ends of a short tube inserted into the upper end of the body; the arm supporting the body; the stage on which the object is placed to be examined; the mirror to illuminate the object; a movable circular plate (the diaphragm) immediately beneath the stage, and the foot that supports the whole. The addition of the objective, or magnifying glass, at the lower end of the body, makes the stand a compound microscope of the simplest form.

The objective is so named because it is near the object to

be examined when the microscope is in use; the eye-piece, or ocular, is so called because it is then near to the observer's eye. Without both of these sets of lenses the instrument is useless.

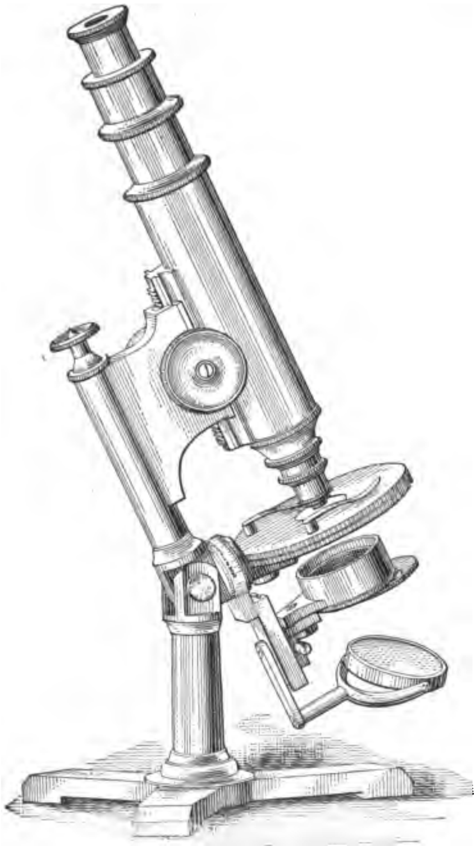


FIG. 2.—A Compound Microscope.

The arm and the foot may be made of either brass or iron, but there should always be a joint between them so that the upper part of the instrument may be inclined. The cheapest stands are made without this arrangement; they must there-

fore always be used in a vertical position, the observer being compelled to hold his head and body in a way that soon becomes exceedingly wearisome. An iron arm and foot are quite as useful as are those of brass, but no stand should be selected without the joint for inclination. Brass looks better, and is more expensive than neatly japanned iron, but is practically no more useful.

Until within a few recent years there were two types of microscopes in use, one having a long, or ten-inch body-tube, and always referred to as the "standard, English length"; the other, with its body about six inches long, and known as the "Continental stand," because it is the form in common use on the continent of Europe. The opticians of France and of Germany never adopted the English standard, and at present there are few microscopical opticians in the known world that manufacture any but the Continental form. In this country the author knows of but one, and of but one firm in England, all others having discarded the long body-tube.

The change has taken place somewhat suddenly, and is perhaps owing to the influence of the teachers in our colleges, universities and biological laboratories, who are permitted, by the Government, to import stands and objectives duty-free, and whose teaching naturally affects the opinions and the conduct of their pupils. A demand has therefore been encouraged for the short or Continental body-tube. To compete with European manufacturers, our own accomplished opticians have been forced to remodel their instruments, and to discard what the old-fashioned microscopist knows as the "standard, ten-inch, English tube."

The investigator that purchases a microscope at the present time will have no choice. He must select the short-tube, Continental form, or none.

The author, who is one of the old-fashioned microscopists, still clings fondly to his long tube, and some of his friends are equally antiquated and of the same opinion. But we are few, weak, and without influence. We were not consulted before the change was made.

The Continental model is said to be more convenient than the former standard, since it may be used in an upright position, or inclined at will.

The eye-piece of all stands consists of two lenses, one at each opposite end of a short brass tube divided internally by a diaphragm. The lens nearest the observer's eye, when the instrument is in use, is the "eye-glass"; the one at the opposite extremity is the "field-glass."

The price of the stand usually includes one or more eye-pieces, but the body-tube of the popular Continental model is so much smaller in diameter than the former ten-inch body, and the eye-pieces are consequently so much narrower, that the field of view is correspondingly reduced in size.

The diameter of the actual field, with a one-fifth inch objective and the 4 (two-inch) eye-piece, is twenty-two one-thousandths (.022) of an inch; with the same combination the apparent field is about six inches. The diameter of the actual field with the same objective and the Continental eye-piece 8 is eleven one-thousandths (.011) inch.

When one of the old-fashioned microscopists first uses a Continental eye-piece on his long tube, as he may use it by means of an "adapter," the small field astonishes him; he feels uneasy, embarrassed, and like a stranger in an unfamiliar land.

The microscopist that has never had any other form will experience none of these sensations, and will feel no regret at the change. To him the Continental model will be as useful, the images as distinct and brilliant, the stand itself as pleasing in appearance, as the long body-tube and its effects appear to be to its old friends, that still cling to it, few in number though they be.

A commendable feature with the Continental type is that it is much less expensive than the old, English form, a fact that will strongly appeal to the beginner seeking his first instrument. For less than one-half of the former price he may buy a complete microscopical "outfit," with which he may be able to do fine work, to which he may add optical

apparatus as he may desire, and which will, if selected with discrimination and properly treated, last him for a life-time.

The eye-piece is dropped into the upper end of the body-tube, where its function is to magnify the aerial image formed within the body by the objective at the lower end.

Formerly, eye-pieces were designated as the two-inch, the one-inch, the half-inch, or often by the letters of the alphabet beginning with A, and sometimes reaching to F.

Occasionally an optician, more accommodating or more progressive than his fellows, would favor the microscopist by marking his eye-pieces with a figure that revealed their magnifying power. This is now the almost universal custom, and eye-pieces, instead of progressing unmeaningly from A to F or further, or from 2-inch to $\frac{1}{8}$ or $\frac{1}{16}$, are distinctly marked from 5, or less, to 27, the figure in each instance representing the magnifying power. The power of the objective being known, the amplification of the combined eye-piece and objective is easily obtained by multiplying the one by the other.

High-power eye-pieces should not be selected by the beginner. They are usually employed only in special work with special objectives. It is recommended, that if two eye-pieces be purchased, they should be the 4 and the 8; if three, the 4, the 8 and the 12.

As these Continental oculars (eye-pieces) are very reasonable in price, when compared with that of the old forms, seldom costing more than two dollars each, the beginner may, even at the start, be able to buy a special eye-piece (the 6, for instance), and to furnish it with an eye-piece micrometer for the measurement of microscopic objects, keeping it exclusively for that purpose. This is not necessary; it is a luxury, but one that the novice will speedily learn to value.

The lower opening in the body always carries a screw to receive that on the upper end of the objective. Several years ago the size of these screws varied widely in stands and objectives of different makers, so that, if the student desired objectives of different make from those accompanying his instrument, he was forced to buy a little piece of apparatus

called an adapter, one end of which was made to screw into the microscope body, the other to receive the objective. At the suggestion of the Royal Microscopical Society of London, all objectives and stands now have screws of the size recommended by that society, and therefore called the "society-screw." Only the cheapest stands of the present day, or those having the least value as instruments for serious investigation, are without this convenience.

Modern objectives are the result of the consummate skill of the accomplished optician. There is no chance work in his methods. Every curve is mathematically exact, and is calculated and positively known before the glass comes to the grinding-tool. Objectives are usually a combination of several lenses, but the union is not accidentally perfected. The maker's knowledge of abstruse optical law tells him the precise result that he may expect from the combination of lenses of certain forms, made from glass of a certain chemical composition. He is the master; his objective is a masterpiece.

The owner of a good objective must not treat it carelessly. He should treasure it, for it is not a common thing. When not on the stand in use, it should be kept in the brass box supplied for that purpose. It should never be left on the stand when not in actual employment.

The part of the brass mounting of the objective which bears the screw is the back; the opposite end, which shows a small flat surface of glass, is the front, or, as it is often styled, the front lens. The glass of this part is soft and easily scratched; therefore, be careful not to let it touch anything hard; especially avoid any gritty substance, or a dirty rag that may hold a minute particle of sand or of hard dust. Never touch it with the fingers, as the oily exudation from the skin will soil it, and interfere with the clearness and the beauty of the image. If the front lens becomes accidentally stained, or is soiled by long use, the objective should be sent to its manufacturer, who can clean it without the great risk to which its owner would expose it, if an attempt should be made to wipe the glass. If fine dust adheres too closely to be dislodged by the

breath, ravel out the edge of a piece of clean old linen or muslin, and with the fringe thus obtained gently sweep the surface.

If the front lens must be wiped by the microscopist, he may use what is called in the trade, Japanese filter-paper, a soft, light, vegetable product from Japan, much employed by dentists in some of their work, and almost as extensively by advanced microscopists for drying the fronts of immersion-lenses, or those objectives which are used with a drop of water, of oil, or of some chemical solution between them and the cover-glass over the object. The paper may be bought from the dealers in microscopical supplies. A piece once used should be thrown away. This use of the Japanese paper was originally suggested by Professor S. H. Gage, of Cornell University.

Another kind perhaps better adapted to this purpose, is Scott's "Clear Sight" paper, made by the Scott Paper Company of Philadelphia. It is intended for the cleaning and polishing of the lenses of eye-glasses and spectacles, but it is admirably adapted for use with microscope objectives. It is heavier than the Japanese paper, it has more "body," is as rapidly absorbent, is rather pleasanter to use, and costs no more. Ten cents will buy a package of, the paper of pleasingly large proportions.

When the objective is to be taken from its box, unscrew the cover and tip the lens into the palm of the left-hand, supporting it with the fingers; pick it up with the thumb and finger of the right-hand against the sides of the tube or brass mounting, and it will be ready, when reversed, to be screwed to the body-tube. If it is not to be returned to the box immediately after use, as will often happen if the student have more than one, and if he desire to examine the object with another power, stand it with its screw-end on the table, and to protect it from dust invert its box over it. The latter can be lifted off in a moment, and the objective will then be ready to be picked up as before.

What objective should the beginner select? If possible,

he should have two, a low-power and a moderately high magnifying power. If unable to purchase both at once, let him by all means first take what is called the one-inch or the $\frac{2}{3}$-inch objective; if he can also buy a moderately high-power, the $\frac{1}{4}$ or the $\frac{1}{5}$ will be the proper glass. But for this he can wait. There is so much to be examined with the low-power objective, that, for a long time, he will scarcely feel the need of others.

The two-thirds inch, if properly selected, need not be expensive, but it should be a good and satisfactory glass, not only at the outset, but when the student becomes an expert microscopist. It will always be useful. When in focus, the distance between the front lens and the surface of the object, or of the cover glass—the working distance—is long. There will therefore be no trouble in using it.

On the Continental body-tube, the magnifying power of such an objective will be, with eye-piece 4, about sixty diameters; with eye-piece 6, about eighty; with eye-piece 8, about one hundred and eighteen; with eye-piece 12, about one hundred and eighty diameters.

After the student has been using the one-inch or the two-thirds-inch objective for some time, and his eye has become educated, he will begin to catch glimpses of minute objects beyond the ability of the low-power glass properly to exhibit. Then he will wish for something more, so that he can look deeper into the little things of Nature.

The opticians make $\frac{1}{8}$, $\frac{1}{10}$, and even $\frac{1}{50}$-inch objectives, which magnify enormously, cost frightfully, and can be successfully used only by accomplished microscopists.

To the beginner, even after considerable experience with the low-power lens, any objective higher than the $\frac{1}{4}$ or $\frac{1}{5}$ will be useless. With either of these he will be well equipped for somewhat extensive microscopical study, until he is ready to undertake original work in some unexplored department of science, or in some partly neglected corner, of which there are many in every scientific field, however well cultivated. Like the low-power, the $\frac{1}{4}$ or the $\frac{1}{5}$ will always be useful.

As the observer's eye becomes better educated, when it

learns, as it will learn, to see minute parts of delicate objects which, at the start, were entirely overlooked, the high-power objective will not be thrown aside, the student will not become dissatisfied with it, but his quickened sight will again catch glimpses of beauty to be examined, and mystery to be unraveled, which are still beyond the power of his best objective, and he will almost unconsciously have advanced another step.

Personally the writer prefers the $\frac{1}{5}$-inch objective to the $\frac{1}{4}$, and such a lens need not be expensive to be good, the working distance is not too short, or need not be, and with the proper eye-piece it will give a magnifying power of about two hundred and fifty diameters.

Every object mentioned in the following pages, is, with the one-fourth or the one-fifth inch objective, visible as described. The writer, in such studies, rarely uses any objective higher in power than the one-fifth.

"The coarse adjustment" is the expression usually applied to the rapid movement of the body produced by turning the large milled-heads, one of which is on each side of the instrument. It is used in focusing, that is, in obtaining a distinct image of the object when seen through the eye-piece and the objective. The image then appears surrounded by a lighted area called the "field of view," or simply "the field."

Very few, except the small, vertical, "boys' microscopes," and some of the cheapest and least desirable American or English stands, are without the coarse adjustment. Occasionally a stand will be seen in which this part is replaced by a broad, cloth-lined, or tightly-fitting collar, through which the body slides, the movement being made by hand. This is unsatisfactory, and such stands should be avoided, as, sooner or later, the body is sure to be suddenly pushed too far down, the objective then coming in contact with the object; an accident to be always guarded against with the greatest care, as the objective, or the object, or both, may be injured.

If the object is destroyed it may possibly be replaced, but a scratched or broken objective can be remedied only by buying

a new one. The microscope-body may, by a careless student, be forced against the object by the use of the milled heads, and a man may fill his stomach with gravel-stones or with powdered glass; but no sane man will so maltreat that organ, and no sane microscopist will so maltreat his objective as to drive it against the object on the stage, when the risk is so great.

The only proper way in which to use the coarse adjustment is *always to focus upward.* When the object to be examined has been placed on the stage, and the light from the mirror is properly arranged, the microscope-body, with the eye-piece and objective, is racked downward by means of the milled heads until the front of the objective almost touches the object, the observer carefully watching that they do not come in contact. Then place the eye at the eye-piece, and nothing will be visible except the brightly illuminated field of view; but, while looking into the microscope, slowly raise the body until the image appears sharp and clear, in other words, until the objective is focused.

It makes no difference whether the distance between the object and the front lens, when focused, is two inches, or the one-hundredth part of one inch, always rack the objective down while you are looking *at* it, and focus upward while you are looking *through* it. This is the single rule that must never be forgotten. It has been said in a joking way, that "Nothing will throw a microscopist into a chill more quickly than to see a friend look into his microscope and *focus down* with the coarse adjustment." Yet men that should know better have been seen to do this reprehensible thing.

In the older instruments, a single small milled-head will be found on the front of the body near the lower end, just above the society-screw. In more recent stands it will be on the arm at the back of the instrument. This is the "fine-adjustment screw"; and although it adds somewhat to the cost, should always be on the stand, if the purchaser desires to use even moderately high-power objectives. For low-powers it is not necessary.

The fine-adjustment screw is so placed that by turning its milled head, the objective, if the adjustment is at the front, or the entire body, if it is at the back, is slowly raised or lowered. When the high-power objective has been imperfectly focused by racking the body *upward*, it seldom happens that the image is distinct as is desirable; therefore the microscopist, by a few gentle turns of the fine-adjustment screw, raises or lowers the objective, until the magnified image has its outlines as sharply defined as are the figures in the best steel engravings. With the one-inch objective, or with others still lower (two, three, or even four-inch), the focus can be accurately obtained by the coarse adjustment alone; but with the $\frac{1}{4}$ or the $\frac{1}{8}$, the fine adjustment must always be used to complete the focusing.

A mistake often made by some who should know better, is to try to examine an object not distinctly in focus. In such cases the strain on the eye is severe and injurious, while the pleasure of observing the preparation is much lessened. The changes made for the better by a few delicate touches to the fine adjustment, can be appreciated only when seen.

Always have the image as distinct as possible. If in doubt as to the focus, after obtaining what seems to be a moderately good appearance, give the fine adjustment a turn or two one way or the other, noticing whether the image becomes sharper in outline and clearer in its general aspect, or whether it grows cloudy and indistinct. If the last, the focus has not been improved, and was probably correct at first. A little experience will make the reader an expert in this important matter.

The stage, on all but the largest and most expensive instruments, is a square or a circular piece of thin metal, with a large central circular opening for the passage of the light from the mirror. Sometimes the metal stage has a glass plate made to slide over it easily. This is a convenience and desirable luxury, but it is by no means necessary. The strip of glass that bears the object to be examined, may just as readily be slipped about under the objective by the fingers directly, as it can be if supported on this movable glass stage. These finger movements require a little practice, but the student will so

soon become accustomed to them, that he will change the position of the object without consciously thinking of the act, and his touch will become so delicate that he will be able, with the slightest pressure, to move the object for a distance so small that it would be invisible to the naked eye.

All this is rather awkward at first, because the object must be moved while the eye is looking through the microscope; and, in addition, if it is to be pushed to what appears to be the left-hand side of the field of view, it must actually be pulled toward the observer's right hand; if the image is to travel up the field, that is, away from the observer as he sits at the microscope, the object must be really slipped toward him, because the lenses reverse the image.

This seems a complicated proceeding, but it soon becomes the easiest thing imaginable. At the first trial, the object will be sure to leap entirely out of the field, because it will be too rapidly moved, and the motion is magnified as well as the object; but the student will soon become so expert that he will be able to make, with fine needles on the stage of his microscope, complicated dissections of the internal organs of the house-fly, or of some other small insect.

The stage will probably have two springs on the upper surface, one on each side. These "spring clips" are to keep in position the glass slide holding the object, unless it is intentionally moved. The slide is put under the clips, and the object, provided it is itself stationary, will remain in the field, where it can be examined quietly and comfortably.

The diaphragm should always be present. It will be pierced, near the edge, with a series of openings of various sizes, to modify the amount of light thrown on the object, the largest opening admitting the greatest amount.

The beginner will at first be disposed to use too much light; indeed this is a fault of many older microscopists. More can be seen with a moderately lighted field, than when the eye is dazzled and half blinded by a fierce glare. Such a blaze is objectionable, not only because it tends to obscure the finer parts of the object, but because it may lead the

student or his friends to condemn the microscope as injuri to the sight, an unjust accusation more than once made.

If too much light is undesirable, do not go to the opposite extreme and strain the eye by forcing it to work in semi-darkness. Keep the field sufficiently lighted to be pleasant to the sight. Turn the diaphragm until the opening giving the most agreeable effect, and illuminating the object enough to show the parts clearly, is under the center of the stage-opening. If the object is very thick or opaque, more light will be needed than if it is perfectly transparent; in such cases use a larger diaphragm-opening.

Some of the best modern stands are equipped with the iris diaphragm, a microscopical luxury, or indeed, almost a necessity. This contrivance is formed of exceedingly thin plates of metal so arranged that, by the movement of a lever, they are made to slide over one another until they nearly meet in the center, where they may form a pin-hole aperture, or they may be so gradually expanded that an opening of almost any desired diameter may be had. By its use the amount of light may be graduated with great delicacy and effectiveness.

The mirror is one of the most important parts of the stand. It should have both a concave and a plane surface, and should not be less than two inches in diameter, so that it may reflect enough light and be easily handled. In the latest styles of stands the mirror bar is arranged to swing from side to side, so as to effect oblique illumination of the object, as well as to rise above the stage, so that light may be reflected down on an opaque specimen, since it is used below the stage for the illumination of transparent substances only.

This swinging arrangement is convenient, and should be had if possible. It is not absolutely necessary, as similar, perhaps better illumination of opaque bodies can be obtained by the "bull's-eye condensing lens," a rather expensive piece of apparatus and somewhat difficult to manipulate successfully. But as the newest and best stands have the swinging mirror, the bull's-eye condensing lens need not be described,

especially since the beginner will not care to examine many opaque objects that may demand stronger illumination than that of ordinary diffused daylight, or of common lamplight.

When the student is ready to examine an object, the stand is placed near the window, or, if at night, the lighted lamp is stood near the instrument, on the left-hand side, one or two inches in advance of the mirror, and the objective is screwed on. The microscope is inclined at a convenient angle; the mirror is moved in various directions, until the light is reflected from a white cloud, if possible, or from the lamp, to the front of the objective, where it can be easily seen. The eye is then placed at the eye-piece, and if the field is imperfectly lighted, as it probably will be, perhaps one-half of it being in shadow, or only a faint trace of light visible at one side, the mirror is slowly moved until the field is brightly and evenly illuminated, or when every part of the circular bright area within the instrument is as well lighted as every other part. The position of the diaphragm is then changed, to be further altered, if necessary, after the object has been focused. This even illumination may at first be a little troublesome to obtain, but as in so many other actions in connection with the microscope, a little practice will overcome every difficulty. The fingers are soon taught; they will speedily do their work without their owner's conscious bidding.

If the reader uses a sub-stage condenser, as he should, and probably will since this piece of optical apparatus is now usually supplied with the stand, he should with it always use the plane mirror. The concave mirror is so made that it focuses the light on the object without the intervention of the sub-stage condenser, and for certain optical reasons should never be used with it.

One secret of proper microscopical illumination with either mirror, is always to receive the light from the lamp on the center of the mirror, and reflect it into the microscope from that center. The lamplight may be seen on the mirror, and should there be central.

When the objective has been focused on the object, and

the illumination appears to be right, remove the eye-piece and look down the body-tube. If the little circular spot of light is not in the exact center, make it so by manipulating the mirror or the lamp or both. For ordinary study with the microscope, never use light in any but an exactly central position.

The specimen to be studied may be permanently preserved, or "mounted," on a slip of glass, under a thin cover and surrounded by Canada balsam, by glycerine, or some other preservative, thus forming a preparation called a "slide," or a "mounted slide," the plain piece of glass without the object being a "slip." The addition of the object changes the slip into a slide. It is well to remember this distinction in talking with the dealers, or in sending orders by mail.

Slides may be made by the student, although to do the work neatly and well demands some skill, and considerable preliminary study of the object, before it can be prepared for the mounting processes; or the slides may be purchased.

It is much better and, in the end, more satisfactory for the owner of the slides to prepare them himself. Certain rare objects, must be bought already mounted but any small object naturally dry can be so easily preserved by placing it in a drop of Canada balsam from the druggist, and covering it by a circle or square of thin glass from the optician, that for the beginner to spend his money for "the foot of a fly," "the sting of a bee," or similar slides that crowd the dealers' lists and shelves, is nonsense, unless he lives alone in the wilderness, and is ignorant of the appearance of a slide. In such a case, to buy the mounted foot of a fly, may be useful to show what is to be aimed at in the preparation of ordinary objects. A few properly mounted slides usually accompany the stand as specimens, or the dealer will supply them.

It adds a zest to such work if the worker can make his own tools. Almost every tool needed at the beginning can be made at home. Slides must be prepared there if one desires to examine any of the endless variety of invisible animal and vegetable life with which the great world teems.

All the objects referred to in this book may be studied when only temporarily mounted; indeed, no method of preserving some of them has yet been discovered or invented. They must, therefore, be studied alive or not at all. And for the beginner this is not only the easiest way, but it is the most instructive and inspiring.

Some things can be examined when dry. Such an object is simply laid on a slip, placed under the spring clips, and the low-power objective used. The ripe seeds of wild plants are easily studied in this manner, and some of them are marvelously beautiful. Small insects can be looked at when dry, but the result is not always satisfactory, unless they are viewed as opaque objects. Usually most objects appear better and show more of their structure, if examined under a disc of thin glass and surrounded by water. Seeds, scales from a butterfly's wing, and many other things, may be viewed and preserved in a dry state, by enclosing them in a cell with a thin-glass cover fastened above. This "cell" and "cover" and fastening process will be described presently.

All plants and animals living in water must be examined in water. To dry them and expect to learn anything about them, or even to obtain a correct idea of their true appearance, is a waste of time, and worse. When the wet specimens get dry on the slide, and you think that you are seeing some wonderful things, add a drop of water and save yourself a probable blunder.

Certain objects, naturally dry, will look better, and will reveal their secrets sooner if examined when wet. This is due to optical reasons not necessary to explain here. The observer, if he is seeking information, and not merely pretty things to please the eye and the æsthetic fancy, will do well if he examine naturally dry objects both in and out of water; but things naturally wet must never be seriously studied in a dry condition.

The most convenient size for glass slips is three inches in length by one in width. Some microscopists use and recommend them when they are two and one-half inches long

by one-half inch wide. These are much too small. It will be better for the beginner at once to select the standard size, three inches by one inch.

These can be bought, and the writer would advise that they should be, as the edges will then be smoothly ground and perhaps polished, although the polish is not necessary.

Slips can be cheaply cut by any glass dealer who has a diamond or glass-cutting wheel, and if thus made, the best, whitest, smoothest, and thinnest glass should be selected. The rough edges of these home-made slips are not pleasant to handle, the student that uses them taking the risk of cut fingers. Otherwise, unless they have a green color, they are as useful as the more expensive ones sold by the dealers. But since a gross of really beautiful slips may be bought for a dollar, to cut them at home is poor economy.

A drop of water on a slip of smooth glass is not easily kept in position. When the slide is placed on the stage, and the microscope inclined for use, as it always should be, the water will surely run away, and will probably carry the object with it. If the microscope is not inclined, the convex surface of the drop, and its tremulous movements, will so affect the light that the image will be distorted, and the observer will obtain erroneous impressions. A piece of glass placed over the water will flatten the surface, the distortion of the image will be partly counteracted, and capillary attraction will keep the liquid from entirely running out.

Ordinary glass is too thick for this purpose; consequently thin glass prepared for microscopical use must be purchased. This varies from No. 1, measuring from about $\frac{1}{150}$ to $\frac{1}{200}$ inch in thickness; No. 2, about $\frac{1}{100}$; and No. 3, from $\frac{1}{50}$ to $\frac{1}{75}$ inch. No. 1 glass will be the proper thickness. It can be obtained either in circles of various sizes or in squares.

For permanent mounts the circles are usually employed. For temporary purposes, for the examination of an object not to be preserved for future use, or when many examinations of separated parts of the same large specimen are to be made, the writer much prefers thin squares, and always uses them.

They are pleasanter to handle, they are more easily wiped dry and with less liability to breakage, and their cost is somewhat less than that of circles of the same thickness.

The matter of cleaning this thin glass is an important one, and unless the "knack" is soon learned, the beginner will be surprised by the rapidity with which his covers will disappear. This skill is readily attained. The writer has had the same thin square of No. 1 glass in use for three months continuously, frequently removing and reapplying it during the hours of daily evening work, in which it did important service, and in the end he felt an affection for it as for a good friend. A hasty move while cleaning it, or a little undue pressure, finally sent it on the way that thin covers often travel.

To clean such glass without much risk of breaking it, take the square with two opposite edges, that is, with the edges where the glass was cut, between the thumb and finger of the left hand, and with a piece of soft, old muslin held smoothly over the thumb and forefinger of the right-hand, gently wipe both surfaces at once, rotating the square when necessary. The secret of success is care, gentleness, and no wrinkles. It was probably a wrinkle in the muslin that ruined the writer's pet cover. A punishment is a good thing sometimes; the microscopist that should begin to think that he is skilful enough to avoid breakage of covers for more than three months, might become insufferably conceited and a nuisance to his friends.

A simple device for this purpose, one with which it is scarcely possible to break even the thinnest cover, is made from two flat, smooth blocks of wood, each covered with chamois skin drawn tightly and smoothly across one surface, and so tacked around the sides that there shall be no danger of contact between tacks and glass. Place the cover on one block and rub it with the other. When that surface is clean, turn the whole thing over, and polish the other side in a similar way.

A glass square, however thin, dropped on a delicate animal or plant is likely to crush it, and to destroy all resemblance

to anything that ever lived. Some means must be devised to support it at a short distance above the slip, so that the living creatures may have room in which to move about, and the plants may not be too much flattened. This is done by making a ring of cement on the slip, thus enclosing a circular space called a *cell*, which can be made of any depth by applying more after the first application has dried, or by freely using a thick cement.

The opticians offer several preparations of the kind for sale, all of which are useful for special purposes; but the one that seems to be the most convenient, the one that may be easily prepared by the novice, is shellac dissolved in alcohol. The solution may be made as thick as is desired by allowing some of the alcohol to evaporate, or be thinned by the addition of more. It should be thick enough to flow freely from a small camel's-hair brush, but not so thin as to spread in an irregular film over the glass. As shellac dissolves slowly in alcohol, it is better to add more of the latter than will be needed, and to thicken the solution by evaporation. It will keep for any length of time in a tightly closed bottle.

A ring may be built up with a camel's-hair brush and this cement, either by the hand alone, or by a little machine called a "turn-table," manufactured for the purpose. These turn-tables spin perfect circles exactly in the middle of the slip. They are somewhat expensive, and, unless the microscopist has considerable work to do with the mounting of objects, they are of rather limited utility and not absolutely necessary.

If you have none, draw in the center of a strip of white pasteboard the size of a slip, a circle in black ink, and use it as a guide to the brush with which you make the ring, after the slip has been laid on the cardboard. The hand cannot be so steady as a flat disc rapidly rotating on a central pivot, and the circles will not be so perfect, but they will be practically as useful. To get the ink circle in the center of the paper, draw a pencil line diagonally across the parallelogram from each upper corner to the opposite lower corner, and use

the point at which the two lines intersect as the center of the circle. The glass slip can be kept in better position, and the whole may be turned about, if the pasteboard be fastened to a strip of wood, and a small pin be driven into each corner.

Hold the slip for a few moments over the lamp-flame, until the ring, when cold, becomes hard. Do not let the shellac boil, for the bubbles will never disappear, and will weaken the cell. These hardened rings adhere firmly to the glass, and have the advantage of being rapidly made.

Dealers in microscopical supplies offer at a reasonable price, rings of tin, rubber, glass and transparent celluloid. These vary in thickness from the one-fiftieth to perhaps the one-tenth of an inch, and in diameter from five-eighths to seven-eighths of an inch. They should be attached to the slip by shellac, and the thinnest selected, unless the microscopist desires a specially deep cell for specially large objects. These form cells that are not only beautiful, but useful. They are commendable, provided the microscopist does not desire to use the turn-table, nor the hand-made rings of cement.

The microscope is intended for the examination of small objects, and of small parts of those small objects. Although the field appears to be several inches in diameter, the actual space seen is really minute. The real field of a one-half inch objective is only $\frac{1}{20}$ of an inch; that is, the objective will, at one time, magnify a surface of the object only $\frac{1}{20}$ of an inch in diameter. The actual field of the $\frac{2}{3}$-inch objective, with a low-power eye-piece, is about $\frac{1}{12}$ inch; with the $\frac{1}{5}$, it is less than $\frac{1}{50}$ inch; with the $\frac{1}{8}$, it is less than $\frac{1}{80}$ inch. The microscopist must deal with small things, small quantities and small spaces.

The reader should remember this when he prepares his temporary mount, and put no more than is needed in the cell. The shallower the cell, and the less it contains, within reasonable limits, the better. When the observer becomes unexpectedly annoyed by a strange indistinctness in his temporary mount, when the field suddenly appears foggy or per-

haps "milky," while the same objective showed the previous preparation with beautiful distinctness and clearness, let him examine the slide, and more frequently than not, he will find that he has tried to do too much, and by filling the cell too full, has put a burden on his objective that it cannot bear.

But when the cell has been made, the object is to be placed within it in a drop of water, the thin cover dropped over it, and the preparation will then be ready for examination. How is this minute, generally invisible object to be got into the cell? A glass tube about $\frac{1}{10}$ inch inside diameter, and as long as may be convenient, several needles in wooden handles, and a camel's-hair brush with a small, smooth stick thrust into the quill, will be needed.

The needles are used for spreading any small mass evenly over the cell, and in disentangling and arranging the parts of any comparatively large object, as well as for lifting the thin cover from the cell so that it can be easily seized by the fingers, or for tilting it up in the box, where the thin squares and circles should always be kept. Fresh-water Algæ (Chapter III), for instance, that are found so abundantly in almost all still water, where they often form delicate green clouds, or thread-like streamers adhering to other plants, to dead leaves, or to water-logged sticks, are almost sure to be transferred to the slip in a heaped and tangled mass, that only two needles with gently persuasive movements can straighten out for microscopical study. If an attempt is made to examine such a confused heap, the thin cover cannot be forced to lie flat without crushing the delicate specimen; if the cover is tilted the objective cannot be properly focused.

To make these useful tools, with pliers thrust fine needles head first into parlor matches, after the phosphorous ends have been cut off. These round sticks make handles convenient in length and pleasant to use. It is well to have half a dozen or more of these needle-bearing matches lying where they can be picked up whenever wanted. If the student desires to dissect insects, nothing can be so useful as fine needles for cutting and tearing minute parts, and for separating

delicate tissues or organs. No knives have been made to equal them for this purpose.

The glass tube is the "dipping-tube." It is one of the most important little pieces of apparatus that the microscopist can have on his table, if he intends to study aquatic life. With it he can pick up any small object that may be visible in the water, transfer any selected matters to the slip, or make the dip that is made by faith, with the assurance, that although the tube may seem to be filled with water only, it will be pretty sure to have captured something interesting, novel, or beautiful.

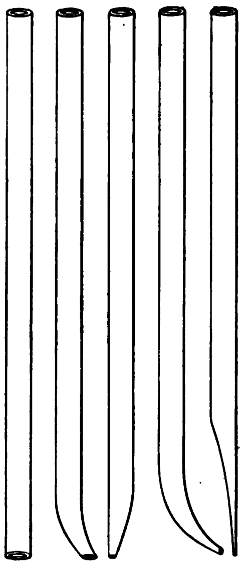


FIG. 3.—Dipping Tubes.

He can fill the tube with water and allow it to escape in a miniature torrent, or drop by drop; and he may allow a drop to enter or to flow slowly out at his will.

Some workers prefer a tube with a hollow rubber-bulb attached, the water and the contained objects being drawn up by the expanding ball, and forced out by its compression. The writer is prepossessed in favor of the simple tube, as it is less complicated, more easily cleaned, and its contents are more completely under control. Several are shown in FIG. 3.

To use it, place the tip of the forefinger firmly over the upper end, and dip the lower into the water above and near the object desired; lift the finger, and the water will rush in until it is level with that on the outside; close the upper end again, remove the tube, and the water will remain in place as long as the finger stops the upper opening; remove the finger and the water will at once flow out. By the proper regulating of the pressure and of the finger movements, the water may be made to escape drop by drop, or in a sudden

rush. In this way any small aquatic object may be easily transferred to the slip, and as readily washed off by a sudden outward flow from a full tube. If the object descends too slowly, rotating the tube will hasten it.

Until recently I supposed that this little affair is common property, and that the principle on which it acts is understood by everybody. But when I called on a gentleman, a member of a scientific society, to obtain water in which certain plants were growing, he expressed surprise at the performance, and called his wife to witness a new and curious method of taking up water, with nothing but a glass tube and one finger. His astonishment was amusing; but how much more so was that of a druggist, who had a teaspoonful of deposit at the bottom of a conical glass vessel with a quart of water above it, and who, after running about for bottles and jars to hold this water, which he thought must be poured off, returned to find the deposit removed, and in a small phial in the writer's pocket, and the quart of water undisturbed. "Why," he said, "that is strange. I never saw the like. How did you do it?"

It is often convenient to have several dipping-tubes, some straight, others drawn out to a point, and some curved (FIG. 3) so as to be readily directed into a narrow corner. A glass tube is easily pulled out to a fine extremity or variously curved, when softened in an alcohol flame. A spirit-lamp may not always be within reach, and is not necessary, for the student can make a Bunsen burner almost without cost, and use it successfully, if his home is supplied with illuminating gas.

Prof. Austin C. Apgar, in *Science News and Boston Journal of Chemistry*, has, under the title, "A Bunsen Burner for Two Cents," described a simple piece of apparatus that is a boon to any one desiring to do a little amateur glass-blowing. A strip of tin 6 inches long and 2 wide, is rolled, without solder or fastening of any kind, into a tube about half an inch in diameter, after 2 holes, each $\frac{1}{4}$ inch in diameter, have been punched in it so that they shall be on opposite sides of the tube, and high enough to be a short distance above the tip

of the gas-burner. This simple arrangement is forced over the ordinary burner, so that the holes are just above the tip, the elasticity of the tube holding it in place; the gas is lighted at the upper end, where it burns without smoke and gives a strong heat, the flame being easily regulated, and, with ordinary care, not flashing into the tube. It is entirely successful.

Evaporation of the water will take place from beneath the thin cover, sometimes rapidly, and the observer will at first be surprised by the swiftness with which his objects will be swept out of the field before an advancing wave that leaves the glass nearly dry behind it. The water in the cell is drying up, and a fresh supply must be added, if the objects are not to be lost.

Here is another advantage in the use of square covers on circular cells. The four corners project beyond the cement ring, and by applying the camel's-hair brush, wet with water, to the slide beneath any one of these projections, the drop will run in and fill the cell by capillary attraction. This supply is much more easily added than if circular covers are used, and after a little experience, the fresh drops can be applied by the microscopist while his eye is at the eye-piece, the hand alone guiding the wet pencil, and the eye taking note of the rush of the incoming wave and of the effect. The student will soon become such an adept, he will be able to add so small a supply at each touch of the wet brush, that the movement of the capillary wave will not be strong enough to float the object out of the field.

The secret of success here is in not having too large a brush, and in not filling it too full of water. At the beginning of daily evening work, the brush is wetted and thrown on the table to become thoroughly moistened, when a single dip into the source of supply, with a slight shake, to prevent dripping, takes up enough, although some pressure of the brush against the slide may be needed to squeeze out a small drop. It is better to make several journeys to the water than to lose a desirable object. A dipping-tube adds too

much at once, and cannot be so readily controlled as a brush.

Microscopic animals, although so minute, require much oxygen to keep them well and active. A temporarily mounted slide soon loses its freshness, and the enclosed creatures are speedily smothered. It is, therefore, sometimes an advantage to hasten the evaporation so that a supply of revivifying water may be added.

For this purpose, scrape from the opposite sides of the shellac cell, a quarter-inch space so as to leave an unobstructed entrance for the water from the wet brush. These spaces will also give the air freer access to the cell, as well as hasten the desired evaporation. They leave two curved supports for the square cover, one at the top, one below.

In this simple affair I have kept Infusoria and other small creatures alive and well for several hours in the evening, or until I was compelled to leave them, and have washed them into the aquarium in as good condition and as lively as when first imprisoned.

Here the secret of success is in leaving enough of the cement ring to support the cover properly and to lessen the force of the inflowing water-supply, and in having the cell shallow or deep according as the animals are microscopically small or large.

But it often happens that a certain specimen is to be studied for a long time, a whole evening, for instance. To be continually supplying the water lost by evaporation is not convenient, the student often becoming so absorbed that he forgets this one of Nature's laws until he suffers the penalty, and probably loses the object. At such a time an arrangement is needed for supplying fresh water continuously, and without demanding much attention. Such a contrivance is easily made.

With a triangular file cut one of the smallest homœopathic phials in two, throw away the upper half, and cement the lower to a little, oblong or square piece of ordinary glass, or of a broken slip. Attach this to the slide by a drop of

glycerine, taking care not to use too much, or the square will glide out of place when inclined. Fill the bottle with water, coil into it one end of a doubled, loosely twisted thread of sewing-cotton, and place the other end in contact with one side of the cover, as shown in FIG. 4. The water will pass down the thread to one edge of the cell, where it will flow under as evaporation takes place from the other three sides.

This usually works well. The secret of success is to have the reservoir not more than three-quarters of an inch from the cell, to keep it always full of water, and to have the doubled thread applied closely against the edge of the cover. If the water-supply is too great, and the cell is disposed to overflow, shorten the end of the thread against the cover; if not enough,

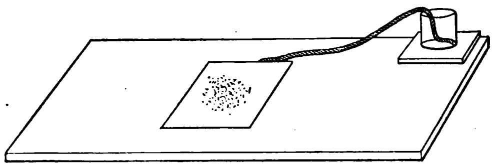


FIG. 4.—A Growing-slide.

lengthen tne thread, and do not allow it to touch the slide in its course from the reservoir to the cell.

Again, the observer will frequently want to make a growing-cell of the slide, on which he may accidentally have placed a desirable or a beautiful object; that is, he desires to preserve the specimen for several days without disturbing it or taking the risk of losing the invisible thing. He may also wish to watch its growth and development. A reservoir for a water-supply is necessary. An "individual" butter-dish makes a good one.

Place the slide across the dish, apply a doubled thread of sewing-cotton along one side of the square cover, so that each end shall hang down into the reservoir, and fill the latter with water, which will then pass up along the thread, and keep the cell full for as long a time as may be desired.

The only objection to this little affair is, that after a few days' use, the salts in the water will crystallize on the cover, and so prevent the absorption of oxygen from the air. No growing-cell is free from all objectionable features; none can quite imitate natural conditions; the animal or plant dies before long, either falling to pieces, or becoming buried beneath a mass of fungi.

This form will supply an abundance of water, if that in the dish is always kept in contact with the lower surface of the slide. This, and the contact of the thread with the edge of the cover, are the only things whose absence will result in defeat.

As the reader already understands, the object must never be examined in water without being covered by either a thin-glass circle or square; the importance of this little piece of crystal must not be forgotten. But often, in lowering it over the wet specimen, small bubbles of air will be caught and not noticed until magnified, when, if seen for the first time, they appear wonderful, if not startling.

Some strange statements have been made and discoveries announced, whose only foundation has been minute air-bubbles which the observer did not recognize. A man once described a marvelous something that he had found in a cancer, but that proved to be a magnified air-bubble. Another proclaimed in print that he had discovered "the microbe of the grippe." This, too, proved to be an air-bubble.

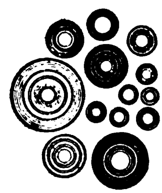


FIG. 5.—Air-bubbles.

These little air-drops often play an amusing part at the beginning of the microscopist's career. In FIG. 5 are shown several of different sizes. Let the student examine a drop of saliva or of soapsuds, and he will in future be able to recognize the troublesome things. Pictures or words cannot convey so true an idea of their appearance as a single glance at the bubbles themselves. At times they become entangled in the parts of an object in such numbers as to interfere with

its examination. In these cases nothing can be done except to lift the cover on the point of the needle, and slowly lower it, or remove it entirely, add more water, and reapply it carefully.

In appearance the bubbles are usually circular, with a broad black border which varies in width and depth of color as the objective is raised or lowered. Near the margin is a bright ring, and in the center a bright spot. They often float about, and this movement adds much to the wonder with which the novice usually regards them.

If the student will have a note-book in which to jot down his observations, or to keep a list of the objects examined, it will not only aid him in forming habits of accurate observation, but will be of great interest when he has become an accomplished microscopist. The entry may be simple, and may be made to serve as a memorandum of items to refresh the memory.

If the student can draw the microscopic objects that interest him, although the sketches may not be artistic they will help him to remember, and a collection of such drawings will be as interesting and valuable as a note-book. In talking to friends about microscopical matters, a single rough sketch will do more than many words to help them understand. If you can look at the object and make the sketch, you will like it better, and will do yourself more good than if you bought and used the drawing apparatus called a camera lucida and for sale by the dealers.

This camera lucida is a glass prism, so arranged that when it is put over the eye-piece, and the microscope placed in a horizontal position, the magnified image seems to be projected on a sheet of paper spread on the table just under the camera, but with a space of several inches between them. By placing the eye in the proper position, and looking down toward the table through the edge of the prism, both the image and the pencil-point can be seen at once, and the outlines traced. It is a rather expensive apparatus, and difficult to use without a good deal of practice. The secret of success is a faint light

on the object, a strong light on the paper, and a long, sharp pencil-point. The blackening of the pencil-point with ink is an advantage.

This is the old-fashioned Wollaston-prism camera lucida, and is as useful as any of the more modern forms so plentifully noticed in the catalogues of microscopical appliances. All are modifications of Wollaston's original prism. Some have a lens to magnify the pencil-point, others are so made as to be used with the microscope upright, others with it inclined.

A micrometer is for measuring objects under the microscope. It is made by ruling a number of short lines on glass, the spaces between the lines varying from $\frac{1}{100}$ to $\frac{1}{1000}$ inch or less. Micrometers are said to have been ruled with one million lines to the inch, but the human eye, using the best and highest-power objectives, has never seen them and never will. All micrometers are prepared by a ruling machine made for the purpose. They are of two kinds, the stage micrometer and the eye-piece micrometer.

The beginner will not need a micrometer of either kind, but he may desire to know how to use them. Place the stage-micrometer on the stage, turn the microscope horizontal, with the camera lucida fitted to the eye-piece. With the low-power objective focus the lines that are $\frac{1}{100}$ inch apart, and draw them on the paper. Do the same with every objective, drawing the $\frac{1}{1000}$ inch spaces with the $\frac{1}{4}$ or the $\frac{1}{8}$ inch lens.

These drawings will form a scale for measuring the drawings of the magnified objects. If the magnified object, when drawn, occupies two spaces of the paper scale made from the $\frac{1}{100}$ inch micrometer-spaces, the object will measure $\frac{2}{100}$, or $\frac{1}{50}$ inch in length; if five spaces of the scale, it will measure $\frac{5}{100}$, or $\frac{1}{20}$ inch in length; if only one-half a space of the scale, it will measure one-half of $\frac{1}{100}$ of an inch; if one-fourth of the scale-space, its actual length will be $\frac{1}{400}$ inch.

If the $\frac{1}{4}$ or the $\frac{1}{8}$ inch objective or a higher power is used in making the scale from the $\frac{1}{1000}$ inch micrometer-spaces, each division on the paper will represent $\frac{1}{1000}$ inch, and if

the drawing of the object measures two of these spaces on the scale, the real length of the object will be $\frac{2}{1000}$ inch, or $\frac{1}{500}$.

It is obvious that the stage micrometer can be used not for measuring objects directly, but only by applying the drawing of the magnified micrometer-spaces to the drawing of the magnified object.

The eye-piece micrometer is a glass disc of such size as to slip into the eye-piece mounting, and rest on the diaphragm always found there. The glass is ruled in groups of parallel lines, the value of whose spaces must be ascertained by the use of the stage micrometer.

With the latter on the stage and focused, place the eye-piece, carrying its micrometer, in the body-tube and rotate it until the lines on both micrometers are parallel. Count the number of spaces on the eye-piece micrometer needed to fill exactly a single space on the stage micrometer, divide the known value of that space by the number of spaces in the eye-piece micrometer needed to fill it, and the quotient will be the value of a single space of the eye-piece micrometer. If three spaces of the ocular micrometer fill one of the $\frac{1}{1000}$ inch spaces of the stage-micrometer, each space on the former represents $\frac{1}{3000}$ inch. This process must be repeated with every objective, and the ocular micrometer must always be used in the same eye-piece.

With this, the object may be measured directly, by counting the number of spaces that it occupies in the ocular micrometer, and multiplying the ascertained value of each space by that number. An object just filling three of the $\frac{1}{3000}$ inch spaces of the eye-piece micrometer would be $\frac{3}{3000}$ or $\frac{1}{1000}$ inch in length.

The stage-micrometer can also be used to ascertain the power of the microscope. If each of the $\frac{1}{100}$ inch spaces measures, when drawn on the paper, $\frac{1}{10}$ inch, that combination of eye-piece and objective will have a magnifying power of ten diameters; if each $\frac{1}{100}$ inch micrometer-space measures $\frac{4}{10}$ inch, the power will be forty diameters; each, therefore, corresponds to ten times. If the $\frac{1}{1000}$ inch micrometer-spaces

measure, when drawn, $\frac{1}{10}$ inch, each tenth corresponds to a power of one hundred times; if the $\frac{1}{1000}$ inch spaces, when magnified, measure ten-tenths, the power of that eye-piece and objective is one thousand diameters, or ten times one hundred; if five-tenths, five times one hundred.

Although the metric system of measurement will probably never entirely supersede that by the inch, with its parts and combinations as now in use, microscopists have found a certain fractional portion of the meter to be useful and convenient for the measurement of microscopic objects.

To this minute space they have given the name micron. After much discussion and many suggestions, the space represented by $\frac{1}{25000}$ of an inch, the $\frac{1}{1000}$ of a millimeter, has been selected as the unit of microscopical measurement. That small distance is now known as a micron, and in microscopical literature is represented by the Greek letter μ. An object described as being from 25μ to 50μ in diameter, means that it is from 25 to 50 microns, or from $\frac{25}{25000}$ to $\frac{50}{25000}$ of an inch in width.

If the microscopist intends to do even a little microscopical measuring, it will be well for him to have a stage micrometer, ruled in millimeters and in hundredths of a millimeter, from which he may calculate the value of the spaces on his eye-piece micrometer in terms of a micron.

The $\frac{1}{25000}$ of an inch is a minute distance, and the space of any eye-piece micrometer will surely include more than one micron. Such spaces only one micron in width would hardly be manageable. The lines on the writer's eye-piece micrometer, when used with the $\frac{1}{6}$ inch objective, are 7.5 microns apart; with the $\frac{1}{8}$ objective they are 5.5 microns.

Stage micrometers are the result of much care and skill on the part of the preparator, yet ordinarily they are not expensive. If the microscopist owns a stage micrometer ruled in parts of an inch, and does not care to buy another in parts of a millimeter, he may still calculate the value of the eye-piece spaces in terms of a micron, by the use of his stage-plate. If he has the value of the eye-piece spaces in fractions

of an inch, he need only divide 25,000 by the denominator of the fraction, and the quotient will be in microns. A space $\frac{1}{3500}$ inch wide is equal to about 7.2 microns ($25,000 \div 3500 = 7.1421$). This is not mathematically accurate, but it is nearly enough so for practical purposes.

The measurements of the objects recorded in the following pages are not intended to be accepted as mathematically accurate. That would be unnecessary, or perhaps impossible. The measurements are average or approximate. No two maple trees, no two trees of even the same species, have exactly the same height. No two leaves on the same tree are precisely alike. No two human beings are of exactly the same height. We recognize the average, and qualify it by saying "about," or "nearly." Microscopic plants and animals have, as species, an average length or diameter. From this the individual one may vary within recognizable limits, and still be within the average for the class. When a microscopic creature is said to be $\frac{1}{200}$ inch or 125 microns, long or wide, the reader should not be surprised if his micrometer records $\frac{1}{250}$ inch, or 100 microns. The discrepancy may be in the incorrect spacing of the micrometer, in the reader's incorrect estimate of those spaces, in his difficulty in measuring an actively moving animal, or in the variability of the creature itself.

Much of the perception of delicate and minute microscopic structure depends upon the training, the education, of the eye, and of the brain behind the eye. The observer need not hope to give the microscope mirror a shove, the coarse adjustment a careless turn, the slide a thoughtless push, and expect to see the secondary structure of a Diatom, or the flagellum of a microbe. If he does, he will be disappointed. Such work is fine work, and can be done only with care, intense application, and after perhaps a prolonged use of the instrument, and an equally prolonged education of the eye. The writer has had these facts forced upon his notice more than once. Because they are true and important, he calls the reader's attention to them. The writer has seen plainly, clearly and

with beautiful sharpness, the fine structure of a Diatom, while a friend, taking his place at the microscope, has declared that the object was smooth, blank and structureless. The fault was not in the microscope, that was unchanged; it was not in the objective, that was first-class; it was not in improper illumination, that was correctly adjusted. Where the fault was, need not now be repeated.

If, at the first attempt, the reader fails to see the cilia on the frontal disc of a Rotifer, or the nucleus in the body of *Amœba*, he need not be astonished. All such trouble will pass, and be remembered with amusement.

The reader will find these statements repeated more than once in the following chapters. The author does not hesitate to repeat, when repetition serves "to point a moral," to instruct the novice, or to call attention to an important fact. I have said that every object mentioned in the subsequent pages is, with the $\frac{1}{6}$ inch objective, visible as described, but I do not say that the inexperienced observer will be able, at first glance, to see all of the fine features. He will not. But the structures are there, and the reader may see them if he will. When he uses the microscope, the microscopist is training his fingers, his delicacy of perception, his eye-sight, his ability to concentrate his attention, his powers of observation, and his brain. These things are not accomplished in a moment.

This training of the eye to see minute objects is really a training of the brain. Prof. S. H. Gage has recognized this fact, and has voiced it well in his book entitled "The Microscope and Histology." He says: "In considering the real greatness of the microscope, and the truly splendid service it has rendered, the fact has not been lost sight of that the microscope is, after all, only a means of getting a larger image on the retina than would be possible without it; but the appreciation of this retinal image, whether it is made with or without the aid of the microscope, must always depend upon the character and training of the seeing and appreciating brain behind the eye. The microscope simply aids the eye in furnishing raw material, so to speak, for the brain to work upon."

CHAPTER II

COMMON AQUATIC PLANTS USEFUL TO THE MICROSCOPIST

THERE are several common plants floating freely in the water, or more or less firmly rooted in the mud at the bottom of shallow ponds and of slowly flowing streams, that are important to the student of microscopic aquatic life. This may be by reason of their own interesting or peculiar structure, or on account of the minute plants and animals that live among their tangled leaves, or attach themselves to the stem or other parts. These entangled objects are more easily and surely captured by transferring the larger visible growth to a small vessel of water than in any other way.

Most of these aquatic plants have their leaves divided into fine, thread-like leaflets. They have "dissected leaves," as the botanist names them. These filamentous leaflets become favorite resorts for invisible animals, which attach themselves to the narrow divisions, and feed on the free-swimming kinds that likewise find the same places attractive. If the student desires to gather microscopic material, let him find any of the following plants, and he will be pretty sure to get what he wants.

He should remember that by lifting the plants out of the water, many of the slightly adherent creatures that he most desires will be washed away. The plants should be slowly and carefully drawn to the shore, lifted out in a tin dipper and poured into a wide-mouthed bottle. The small tin dipper will prove a convenient implement for all kinds of microscopical collecting, as a handle of any length can be made by thrusting a stick into the hollow handle of the vessel. If the dipper is not accessible, the plants may be gently pushed into the bottle, after it has been partly submerged so that it lies parallel with the surface of the water.

Many of our most abundant aquatic plants have no common English names, probably because most of them bear the smallest and least showy flowers of all other blooming plants, and for that reason fail to attract the attention of the ordinary observer. In referring to them, the beginner must use the scientific names, or learn the meaning of the Latin words and use the translation, usually with awkward results.

It sounds better and is quite as easy, to speak of *Myriophýllum* as of the "thousand-leaved plant," which the word means. Many plants might be styled thousand-leaved, another common aquatic one, for instance, which often grows in the same pond with *Myriophýllum*, the *Ceratophýllum*, called "hornwort" because the leaves are rather stiff and horny; and *Lémna*, as a word, is prettier and more appropriate than "duckweed," an ugly term and meaningless, because ducks have no connection with the plant. They will not even eat it.

If the reader is not already familiar with the appearance of the following forms, he need have no trouble in recognizing them, nor in learning their name, although he may never have studied botany; he has only to compare the leaves with the figures in this chapter.

It should be understood that there are many aquatic plants not here referred to, only those being included in this list that afford the most certain supply of microscopic life.

The leaves of many water-plants fall against the stem and cling together when lifted into the air; but if the student will place a small part of the plant in a saucer ("individual butter-dishes" are good for this purpose), he can float them out against the white surface and so compare them with the figures.

RANÚNCULUS TRICHOPHÝLLUS (FIG. 6)

A part of the stem and a single leaf of this plant are shown somewhat enlarged in the figure (FIG. 6). It is not uncommon in ponds and slowly flowing streams. The leaves are dissected into fine, rather stiff and hair-like parts, to which many minute animals, such as *Rotífera* (Chapter VIII), *Vorticéllæ* (Chapter V), and *Sténtors* (Chapter V) are fond of

attaching themselves. The leaves are placed above one another on opposite sides of the long and somewhat brittle stem, and usually rather wide apart. They are what the botanist calls alternate.

Two varieties, or perhaps two species, of this *Ranunculus* grow in the same pond in my locality. In one form or variety (*trichophyllus*), the leaves are dark in color, rather stiff, so that they do not readily collapse and fall against the stem when the plant is removed from the water.

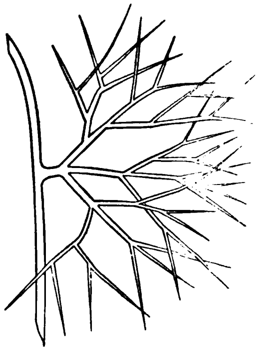


FIG. 6.—Leaf of Ranúnculus trichophýllus.

With this variety, the external, microscopic structure is so nearly characteristic, that a small fragment under the microscope will reveal its identity. The cells that form the cuticle are hexagons, usually with unequal sides. Each division of the leaf, like that of the other variety (*fláccidus*) is terminated by two, often by three, sometimes by four, short, colorless, semi-transparent spines, with an average length of 100 microns, or about $\frac{1}{250}$ inch. Those of *fláccidus* are shorter, reaching only about 52 microns, or about $\frac{1}{480}$ inch.

In the variety *fláccidus*, the leaves are lighter in color, soft, flexible. They fall together and drop against the stem, when the plant is withdrawn from the pond. The cells of the cuticle are not hexagonal, but oblong, rectangular, and four-sided, with parallel margins.

These distinctions are of little or no importance to the microscopist, as both forms are equally well adapted to his purpose, and to the purposes of the adherent or entangled objects that he desires to obtain.

But this *Ranunculus* is indeed so variable, that it is not worth the microscopist's while even to attempt to distinguish the varieties. I have had a specimen, in which the oblong cuticular cells of *flaccidus* gradually changed their form, and

became irregular hexagons, as in the variety *trichophyllus*, and these in turn as gradually became minute triangles.

The whole plant is permanently submerged, except at flowering time in June, when a delicate stalk rises into the air, and blooms with a single, white flower that rests delicately poised on the surface of the water. I have seen these blossoms so plentiful, that the white stars appeared to be as abundant, and were as beautiful as the stars that sparkle in the summer sky.

CASTÁLIA ODORÁTA (White Water-lily, Fig. 7)

Every one is familar with this beautiful flower, this "marvel of bloom and grace," and with its large, almost circular floating leaves. It is to the under-surface of these leaves that the microscopist often goes for several forms of case-building Rotífera, with the certainty of always finding them, together with many and various other kinds of minute animal life. It is likewise an excellent place to search for aquatic worms. You will usually capture these creatures if the lower surface is gently scraped, and the dark mass thus obtained be examined in water.

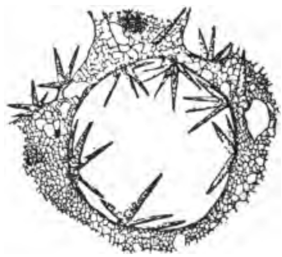


Fig. 7.—Peduncle of Castalia odoráta; transverse section.

But if the scented blossom is beautiful to the ordinary observer, the interior of the flower-stems and leaf-stalks has charms known only to the microscopist. Cut a thin slice from either of these parts and examine it. The sides of the wide openings made by cutting across the internal tubes are studded with crystalline stars (Fig. 7). Three-pointed, four- and five-pointed, they sparkle there like diamonds. They were formed in darkness, and in darkness act their part in the life of the plant.

What that part is we can only guess. Botanists call them internal hairs; but they are hard, sharp-pointed, and brittle. They are hollow, too, and their surface is roughened by minute

elevations, as though fairy fingers had sprinkled them with crystal grains. I seldom see a white water-lily, without in imagination seeing those long stalks rising out of the black mud through the dark water, with their entire length illumined by the sparkling of these internal star-like gems. The whole plant contains them, even the root. The common "spatter-dock," *Nymphœa*, also conceals similar stellate hairs within its stems, but they are here larger and coarser, as become a coarser plant. The leaves of the *Nymphœa* are not a good microscopical hunting-ground, as they usually stand high above the water.

MYRIOPHYLLUM (Fig. 8)

This is not rare in shallow ponds and slow streams. It occurs, at times, in running water, but there it is not worth gathering, so far as any adherent microscopical life is concerned. No running water is a good locality for free-swimming creatures, because the current sweeps them away, or so scatters them that it is not possible to make a collection. But where *Myriophyllum* grows it usually grows abundantly, and forms long green streamers, cylindrical and thick, sometimes more than an inch in diameter, and several feet in length, yet it always looks soft and feathery.

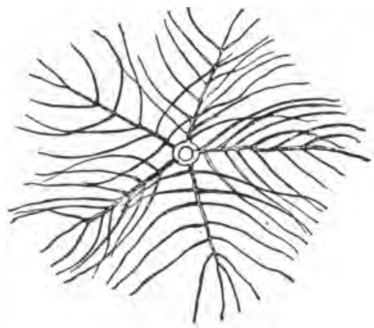


Fig. 8.—Whorl of Myriophyllum Leaves.

The leaves are numerous. Each set is arranged in a circle around the stem; or in "whorls," as the botanist calls the arrangement. One such whorl is shown in Fig. 8. Five dissected leaves are there drawn, but whorls sometimes occur with three or four, the number helping to distinguish the species, of which there are several, all of them closely resembling one another when in the water. The parts of the

leaf are fine, soft, and hair-like, those nearest the stem of the plant being the longest. They are numerous and close together. They thus give the floating streamers their peculiar, thick and soft appearance, and make them an excellent place for the microscopist to explore.

To compare with Fig. 8 a feathery plant which the collector does not know, select a circle of leaves, cut the stem close above and below it, and after floating the separated whorl in a saucer as already directed, or spreading it out on white paper, compare its leaves with those figured. These vary in size in different parts of the plant, the uppermost being the smallest and youngest, the lower the oldest and largest.

Another rather common aquatic plant called *Proserpináca* or "mermaid-weed," so closely resembles *Myriophýllum* when in the water that it has often been mistaken for it. To make such an error is of no great consequence, unless it should lead the observer as it once led the writer, to imagine that he has a rare species of *Myriophýllum*. Yet it is always pleasant, if nothing else, to feel sure, and it is more than pleasant to have a reputation for accurate observation. *Proserpináca* is as useful a trap as *Myriophýllum*, from which it may be easily distinguished because the dissected leaves are not in an exact circle around the stem; one is on one side, the next a little further around and a little higher up, another still further around and nearer the first, but still higher, the whole forming a spiral arrangement which the botanist calls alternate.

Either of these plants is a specially good place for attached Diatoms (Chapter III).

UTRICULÁRIA (Figs. 9 and 10)

Of all our water-plants with finely divided leaves, *Utriculária* is probably the most interesting in itself, and one that can always be recognized at a glance. It is found in long, somewhat branching streamers, floating freely below the surface or very slightly rooted. A leaf of *Utriculária vulgáris*, a common species, is shown somewhat enlarged in Fig. 9,

with the peculiar hollow bladders, or "utricles," that distinguish it from all other plants, and give it one of its scientific names.

FIG. 9.—A Leaf of Utriculária.

These utricles are almost always conspicuous when the plant is taken from the water, as small, green, semi-transparent particles attached to the leaflets. They are not unlike small pieces of jelly in appearance, until examined with the microscope, when their remarkable structure becomes apparent. Until within a few years they were supposed to act as air-sacs to keep the plant afloat. It was even said that they became filled with air or gas at flowering-time, and lifted the flower-stalk and the blossoms above the water. This was interesting, but the truth is more interesting and startling. The plant actually feeds on animals. These bladder-like bodies are the food-traps, they are the mouths and the stomachs of *Utriculária.*

Under the microscope the utricles are seen to be hollow, ovoid bodies, with a narrow, almost straight anterior end, and with several long bristles projecting forward, or away from the body of the utricle, these bristles probably serving as a guide to an opening at their base.

A little animal swims against the bristle, and naturally moves down toward the opening at the mouth of the utricle, which it finds closed by a transparent colorless curtain; this it pushes aside and passes into the trap. The curtain-like valve is attached by its upper and lateral margins, thus hanging before the opening in the utricle, and swinging inward, but so arranged that it cannot be forced outward by any creature small enough to pass within. The power that the valve seems to exert is astonishing. Small fish have been found with the tail, or even with the head inside the utricle, and firmly held by the pressure of the valve. In these cases, however, it seems probable that the struggles of the dying

fish may have wedged it fast, rather than that the valve has held it.

Small worms and worm-like larvæ nave oeen found half in and half out of these fatal traps. Once past the curtain-like valve the little animal never escapes. No sooner has it entered, than it begins to shows signs of discomfort; if it has a shell, it withdraws its legs and head and closes the shell; if a worm or an Infusorium it speedily becomes languid, its movements cease, and it finally dies, as does every creature that ventures into *Utricŭlăria's* utricles. They evidently contain something more than simple water.

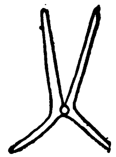


FIG. 10.—Quadrifid process from Inner Surface of Utricle of Utriculăria.

If these bladders are torn to pieces with the needles under the microscope, the remains of many kinds of minute creatures will be seen. The soft parts of the captives have been dissolved, absorbed, and gone to nourish the plant.

The whole inner surface of the utricle is lined by innumerable colorless four-parted bodies, one of which is shown much magnified in FIG. 10. They are distinctly visible only when the utricle has been torn to pieces. They are said to be the glands that absorb the fluid in which the entrapped animals have been dissolved.

CERATOPHŶLLUM DĔMERSUM (FIG. 11)

This is commoner and more abundant than *Myriophŷllum*, for which it is often mistaken, although the two have only a remote general likeness. The leaves of *Myriophŷllum* are fine and soft, those of *Ceratophŷllum* coarse and stiff. In the latter they are whorled, with from six to eight in each circle, but instead of being divided on each side down to the middle line (the midrib), as in *Myriophŷllum*, they appear to separate into two narrow parts near the main stem, while each division then often divides into two other parts. Both these arrangements are represented in FIG. 11, where the whorl is shown separated, as was done in *Myriophŷllum*.

The leaves always bear several small but visible spines on their sides, as shown in the figure. When taken from the water they usually do not fall against the stem, but remain stiffly extended.

The plant is found in still, shallow places, growing in thick masses, with the stem often considerably branched. It makes an excellent retreat for certain Rotifera and worms, but the leaves are so thick and rigid, that they are not so easily prepared for microscopical examination as are those of *Myriophyllum;* they often refuse to lie flat. They thus tilt the cover-glass and allow the water to run away.

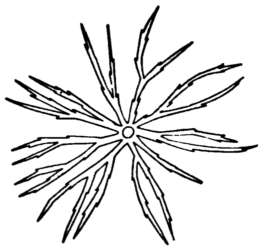


FIG. 11.—Whorl of Leaves of Ceratophyllum.

But with neither of these plants will the student try to place an entire whorl of leaves in the cell. It is always best to clip off with scissors a part of a single leaf, and to examine it for whatever may be attached. Work with the microscope is delicate work. The smaller the object, within certain limits, the better. Many novices make the mistake of trying to examine too large a specimen, or too much of a mass.

SPIRÓDELA POLYRHÍZA (FIG. 12) AND LÉMNA MÍNOR, DUCKMEAT (FIG. 13)

These are small plants, very common, and often so abundant that the entire surface of large ponds is covered by them as by a green carpet. The two plants resemble each other, yet they differ so widely that a glance will distinguish them.

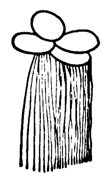


FIG. 12.—Spiródela polyrhíza. About natural size.

Each consists of a small, green, more or less oval leaf or "frond" floating on the water, with one or more rootlets hanging from beneath, but never seeking attachment in the mud. Usually two, three, or four fronds are attached together, so as to form an irregular star. *Spiródela*

polyrhíza, the "many-rooted" (FIG. 12), has the largest fronds, is a deeper green, and, as its specific name signifies, has many rootlets, often a dozen, hanging in a cluster from each. It may always be recognized by this root-cluster, and by the dull purple color of the lower surface. It seems to like the sun better than *Lémna mínor*, and is oftener found abundantly on open ponds. The latter appears to prefer ditches with high banks and shade.

FIG. 13.—Lémna mínor. About natural size.

Lémna mínor (FIG. 13) has smaller, more oval and thinner fronds. It is lighter green in color, the lower surface is never purplish, and it has but one rootlet to each frond.

Both plants have a peculiar little cap on the free end of each rootlet, where it is more easily seen with the naked eye on *Spiródela polyrhíza*, as it is there usually darker than the rest of the filament.

There are several other species, but they are so seldom found that they need not be included in this list. They all multiply by the growth of young fronds from the edges of the old and mature. This accounts for the clusters so commonly seen.

They also bloom, but the flowers are extremely small and rarely observed. The student will be fortunate if he find specimens in blossom. The flowers burst out of the margin of the frond, and consist of only those parts needed to fertilize and to mature the few small seeds.

The rootlets are valuable to the microscopist, as they are favorite places for many just such creatures as he most wants. The lower surface of the fronds, especially *Spiródela polyrhíza*, should be gently scraped in a drop of water for certain Rotifera not often found elsewhere. It is also much visited by small worms, but not so frequently as are the leaves of the white water-lily.

Gently washing the fronds by shaking them to and fro in a vessel of shallow water, will often be rewarded by the appearance of interesting plants or animals that may

rarely or with difficulty be captured elsewhere, or by other means.

ELODÉA CANADÉNSIS (FIG. 14)

This plant is readily recognized by the arrangement of the leaves in circles, or whorls, of three leaves each. Two whorls are shown in FIG. 14. The stem is brittle. Fragments so easily take root that the plant spreads rapidly. Having been accidentally introduced into England, it is said to have grown so fast that it has choked up some of the shallower streams, and to have become an actual nuisance. It is abundant in this its native country, but it never acts so badly here.

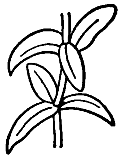


FIG. 14.—Elodéa Canadénsis. About natural size.

The whole plant is semitransparent. The leaves are about half an inch long. They spring directly from the stem, and taper to the point. These leaves, under the microscope, exhibit a remarkable phenomenon.

All plants are formed of cells, or cavities of various sizes and shapes, surrounded on all sides by a delicate membrane called the cell-wall. The cells are seldom, if ever, entirely empty during life. Their contents are chiefly the soft, colorless, jelly-like substance called vegetable protoplasm, and the small green grains (the chlorophyl) that give the green color to the plant. In *Elodéa*, the walls of the leaf-cells are transparent, so that the microscope shows a part of what is taking place within the cell. It is a wonderful sight, for the protoplasm is slowly moving around the walls, carrying the chlorophyl grains with it. Up one side of that microscopic cell travels the strange procession; across, down, up, slowly and steadily the stream and the grains move round and round. Sometimes a little thread of colorless protoplasm leaves the main current and starts across by a shorter road; sometimes the current pauses, stops, and refuses to move again.

The streams in two cells lying side by side may flow in the same or opposite directions, with only the thin cell-wall

between them. What causes these remarkable movements is not known. Cold seems to retard, and warmth to hasten the flow. Often, when the chlorophyl has so increased that the green grains crowd the cells, the circulation ceases, apparently because the chlorophyl has not left enough space for free movement. The botanist calls this movement of the protoplasm cyclósis. It is also beautifully displayed in the long, narrow, ribbon-like leaves of *Vallisnēria*, an abundant and common plant in slowly flowing streams.

To show the cyclósis, the *Elodēa* leaf needs only to be cut off close to the stem, placed in the cell in water, covered by a thin glass, and examined by a high-power objective. The one-inch lens will not show it distinctly. The $\frac{1}{4}$ or a higher power will do so.

The plant is a fruitful source of supply for our two common species of *Hydra* (Chapter VI), which often occurs there so plentifully that two or three hang from almost every leaf.

SPHÁGNUM MOSS (FIG. 15)

On the wet shores of shady bogs, this pale-green moss grows in great patches, thick, soft, and elastic. It is a beautiful plant anywhere; it is especially so when it appears greenly glimmering beneath the shallow water, while the shadows of elder and azalea, and the broad leaves of the tangled smilax vines, make the neighboring thicket dim and cool, even when the hot sun smites the bordering fields.

In such pleasant surroundings Rhizopods (Chapter IV) and Infusoria (Chapter V) are found in abundance. For the former, *Sphágnum* is an unfailing source of supply. The water pressed out of a little pinch of the moss will be sure to contain many individuals and species. From a single small bunch, Dr. Joseph Leidy, when studying the Rhizopods, obtained thirty-eight species and many individuals of those animals, besides numerous active Diatoms (Chapter III) and Desmids (Chapter III).

The leaves make exquisite microscopic objects, on account

of their peculiar and beautiful structure. Each one is formed of two kinds of cells, *A*, and *B*, Fig. 15.

The large cells, *A*, will, when magnified, immediately attract attention. They are hollow, and usually empty, and have a spiral thread running around the wall. At certain stages of growth, the cell-wall also has one or more small openings, *C*, so that the water is able to pass in and fill the cell. This may explain why the plant retains its moisture for so long a time, and why it is so easily wetted. It has become, for these reasons, a favorite substance with the florist in which to pack his bulbs and other small plants, when these are to be carried to a distance.

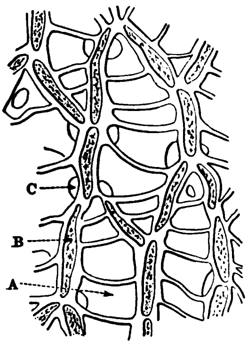


Fig. 15.—Portion of Leaf of Sphagnum. Magnified.

The second kind of cell, *B*, is found between the large ones. These are much smaller, narrower, and commonly contain chlorophyl grains, which, while usually not abundant enough to tinge the whole moss a bright green, yet give it that beautiful pale hue almost characteristic of it. These cells will probably need to be searched for when the beginner for the first time studies a *Sphagnum* leaf, as they are apt not to catch the eye. The difference in structure, especially the absence of the spiral fiber, should serve to distinguish them from the large empty cells that form the chief part, and the characteristic part of the leaf.

The moss seems to have no roots. The lowest parts of the thick mass which it makes are usually dark and partly decayed, and it is there that the Rhizopods are most abundantly found, although many sun-loving forms are equally numerous in the brighter, better lighted upper region. On no account should the student pass a *Sphagnum* swamp, nor even a little patch in those places where it grows more rarely, without taking some to be examined at home. Such a gathering will always repay the slight trouble needed to make it.

The species common in the writer's locality (Trenton, N. J.), is *Sphagnum cymbifolium.* It is probably common throughout the State. It is the only known species with a spiral fiber in the cells of the stem. This makes it easily recognizable. The fiber is slender and delicate, but it is distinctly visible with the one-inch objective.

RÍCCIA FLŬITANS (FIG. 16)

Near the writer's home this little floating plant is so abundant that it often covers small pools with a layer two inches thick. Elsewhere, on larger ponds, it is not uncommon. It often comes to the collecting-bottle tangled in the leaves of *Utriculária, Myriophýllum,* or *Ceratophýllum,* or it floats on still waters in little island-like patches. Its form is seen in FIG. 16, about natural size.

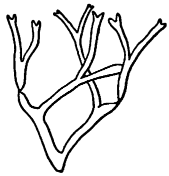


FIG. 16.—Ríccia flŭitans

It has no leaves; it is all leaf; the botanist calls it a radiately expanding frond, with narrow divisions, whose ends are notched. The plant is green, and may be an inch or more wide when spread out. It is often larger and more branched than shown in the figure. It has no roots, but floats freely wherever the currents or the winds may send it. Shady places seem to be its favorite haunts.

As a microscopic object it is rather large and thick, but it forms a good place to examine for certain Algæ (Chapter III), which tangle themselves about it in fine green threads, appear to favor it, and may often be seen with the naked eye, if the single frond is placed in water above a white surface.

There is another species, *Riccia nátans,* much less common than *R. fluitans,* somewhat smaller, and clothed beneath with long purple rootlets, so numerous that they resemble a purple fringe. The two species are thus easily recognized.

CHAPTER III

DÉSMIDS, DÍATOMS, AND FRESH-WATER ÁLGÆ

THE Désmids and the Díatoms are two closely related groups of minute aquatic plants, which the reader will at first probably have some trouble to distinguish from each other; after a little experience he will be able to recognize them at a glance. Both are plants formed of only a single cell, but their beauty and variety of form, their peculiar movements and wonderful structure, place them among the most attractive of living microscopic objects. They are among the most frequent. Scarcely a drop of water from a pool in spring or in summer can be examined without showing a Désmid or a Díatom.

The Désmids are usually found in the freshest and sweetest water. In salt or brackish marshes, where Díatoms flourish as well as in a mill-pond, Désmids never occur. They also seem to prefer open pools on which the sun shines brightest and the shadows are fewest, where they probably seek warmth rather than the strong light, for they seldom form patches on the mud as the Díatoms do, but adhere to the stems of other plants as a green film; or conceal themselves among the dissected leaves of the aquatic vegetation, or among tangled masses of Algæ.

A living Desmid is always green; a living Diatom is always brown. This difference in color makes it easy to distinguish the two groups of plants, although there are other points that may be used by even a color-blind student. The cell-wall of the Desmid—that is, the thin sac which surrounds the soft green contents—is soft and flexible. If the cover-glass be pressed down firmly with a needle, the Desmid can be flattened or squeezed out of shape, and the cell-wall can often be rup-

tured, so that the green chlorophyl and the colorless jelly-like protoplasm filling the plant are forced out.

The cell-wall of a Diatom is hard and brittle. The cover-glass may be pressed upon until the glass breaks, yet the Diatom will not be flattened nor its shape changed. It may roll over and look quite different in form when viewed in another position, but it will probably roll back and appear as at first. It can be fractured, but it breaks as if made of glass or of some other hard and brittle material. The yellowish-brown contents may flow out, but the broken place will not be an aperture torn with irregular, more or less rounded margins, as it was in the crushed Desmid, but the edges will be sharp and angular, and the Diatom will probably break into several fragments. Yet with the most skilful manipulation it is rather difficult purposely to break any but the largest Diatoms, few of which are visible to the unaided sight of the most acute eye. The brittle, hard-coated little plants are often found in fragments, but according to the writer's experience they are broken accidentally, either by being piled on top of one another and so crushed by the cover-glass, or by rough contact with one another when gathered.

The Desmids float freely in the water; many Diatoms do the same. Several species of Desmids are attached to one another side by side to form long bands; many Diatoms are arranged in a similar way. Some Desmids are surrounded by a colorless jelly-like envelope; so are some Diatoms. The Desmids never grow on the ends of stems secreted by themselves, and attached to other plants or to submerged objects; many Diatoms are found growing on the extremities of long, colorless and branching stalks, like microscopic trees, these stems being supported by other objects in the water. Some of the commonest Diatoms will be found in great abundance growing in this way on the leaves of *Myriophyllum*. Any object that may apparently be either a Desmid or a Diatom, is not a Desmid if it is on the end of a stem of its own formation.

Most Desmids have the ability voluntarily to change their

position. They can move from place to place, as they frequently do. When mixed with mud or with other extraneous matters, as they often are when gathered and carried home in a bottle, they will gradually work themselves to the surface, and collect in a green film or line on the side of the vessel next to the window, whence they can be easily taken by the dipping-tube.

Diatoms have a similar power of movement; but they are usually more active, and their motions more rapid than those of Desmids. While the Desmids move stately and slowly in one direction, a Diatom may travel quickly half-way across the field of view, and without a moment's hesitation, and without reversing its position, may at once return by its former path, or dart off obliquely on a new one. A moving Diatom always seems to have important business on hand, and to be desirous to accomplish it. An object that may be either a Desmid or a Diatom, is not a Desmid if it moves rapidly, and changes its course suddenly and quickly.

The cause of this motion is in each case a mystery. Many theories have been proposed to explain it, but none is satisfactory. If the reader can discover how the Desmids and Diatoms move themselves, his name will be remembered among naturalists to the end of time.

The surface of a Desmid may be smooth, finely striated lengthwise, roughened by minute dots or points, or it may bear several wart-like elevations or even spines of different shapes; its edges may be even or notched, prolonged into teeth, or variously cut and divided. It is these ornaments, in connection with the graceful form, and the pure, usually homogeneous green color, that make the Desmids so attractive to every student of microscopic aquatic life.

Fresh-water Diatoms occasionally have tooth-like or bristle-like processes, but they are seldom spine-bearing; yet the markings on their surface are among the most exquisite of Nature's handiwork, and among the most varied. Dots, hemispherical bosses, hexagons, transverse and longitudinal lines of astonishing number and fineness, are among their

many surface sculpturings, the delicacy and the closeness of which defy description by any but the mathematician. So numerous and close together are the surface lines of some, that they are used to test the good qualities of the best and highest-power objectives.

There are no perfectly smooth Diatoms, although many may so appear with a low-power lens. The splendid glasses of the best American makers will compel any Diatom to show how it is marked and roughened.

In each extremity of many Desmids, especially in the crescent-shaped ones, is a small, colorless, apparently circular space, containing numerous minute dark particles in incessant motion. These little granules, that are said to be crystals, are sometimes so few that they may be counted if sufficiently magnified. In other individuals they appear to be innumerable. Their motion resembles the swarming of microscopic bees. It can scarcely be described. The spaces containing them are called vacuoles, and are never present in Diatoms. It is true that in some of the latter, when dying or dead, many minute black particles are visible, dancing and swarming in clusters within the cells, but this "Brownian movement" is common to many microscopic creatures after death, or when in a weakened or a dying condition.

In the Desmids, there is also often seen a circulation of the protoplasm, similar to the cyclósis in the leaf-cells of *Elodêa*, a movement of the cell content never observed, so far as the writer is aware, in any Diatom.

Between the cell-wall and the green coloring matter, the chlorophyl, there is a shallow space filled with colorless protoplasm, and it is here that the circulation takes place. It is a steady, rather rapid flow, several currents streaming lengthwise up and down the cell, and carrying the minute starch grains and other enclosed particles in their course.

It has been said that these currents sometimes enter the vacuoles, and that the latter obtain their supply of swarming granules from the particles in the streams; it has also been stated that occasionally one or more of the swarming granules

leave the vacuole, enter the current, and journey round the cell. These statements are correct.

Although the occurrence seems rather uncommon, it may be the reader's good fortune, as it has been the writer's, to see one or more of these intra-vacuolar crystals leave their spherical dwelling-place, and pass into the protoplasmic stream, to be carried up and down with the currents that flow beneath the cell-wall. The author has seen several crystals thus escape to liberty from the same vacuole, in the extremity of a *Closterium*. With a high-power objective (the $\frac{1}{8}$, for instance), it is not difficult to select a granule in the general stream, and to follow it as the current carries it down one side to the vacuole, and again upward with an ascending current, to continue the round. The vacuoles themselves are visible with a good low-power objective, but to see distinctly the swarming granules and the general cyclósis, a $\frac{1}{4}$ or a $\frac{1}{8}$ is needed.

It will be safe for the student to take as a Desmid any small, flattened, green, freely-floating object formed of one cell only, especially if it be crescent-shaped, or if its borders be indented, lobed, wavy or even spinous. But be sure that the object consists of only a single cell, with its margins thus variously cut and ornamented. It will be safe to consider such specimens as Desmids until they are proved to be something else, an improbable possibility. If the green object is permanently adherent to some support, or if it shows motion of its own body or of any external appendages, it is probably not a Desmid. The movement that carries the plants toward the light and the warmth of the window, is at times visible to the microscopist, always so in its effect. Do not mistake for permanent attachment the entangling of the band-like forms among filamentous Algæ.

I cannot imagine that even the novice can have any difficulty in identifying the genera of the Desmids, unless it may be with those that form long chains or ribbons by the rapidity of their multiplication, or with those that must be seen "end on," until they become recognizable in front, or more correctly, in side view. But even with the ribbon-like forms there need

be no trouble, if it be remembered that no fresh-water Alga with which a Desmid could be confounded, has its borders scalloped, spinous, toothed, constricted, twisted, or with little, arm-like "claspers" tipped by a knob, and reaching across the partition wall from one cell to the next. Any ribbon-like collection of single, cells, therefore, green, without smooth and even or level margins, may be considered a Desmid, until it is proved to be something else, another improbable possibility.

In addition to the Desmids and the Diatoms, almost every pond and stream contains other minute plants of interest to the microscopist, called the fresh-water Algæ, which he probably already knows, if not by this name, at least by their general appearance, for they form those green masses floating like a scum on the surface, or those soft green clouds so commonly attached to sticks and stones and dead leaves. The Algæ often have a repulsive appearance as they collect in thick and heavy patches, but under the microscope they reveal beauty undreamed of.

All those slimy, slippery, green streamers usually so abundant in still water during the summer are Algæ. The reader need have no trouble to recognize them as Algæ after a little experience, but since he at first may be somewhat uncertain as to which of the three classes of plants his specimen may belong, the following Key has been constructed to aid him. To use it, compare the plant with the description in the following way.

Suppose the specimen is a single cell, shaped like a crescent, as described in the first sentence of the Key. The reader will notice (*a*) at the end of the line, which means that he shall now seek a description somewhere in the table below with *a* at the beginning of the line. Finding three such lines, he reads the first: "Color green," which is the color of the specimen under the microscope; "the plant a floating hollow sphere," which does not describe it, since it is crescent-shaped. He then reads the second "*a*" line: "Color green, the plant not a hollow sphere," which is correct, as his plant is a crescent. The (*b*) at the end refers to another line below headed

by *b*. As there is only one such, the plant must be a Desmid. To learn which of the numerous Desmids it is, he turns to Section I of this chapter, where is another Key to help him to find the name of the genus.

Suppose that he obtains a floating mass which, when lifted on the hand or in a dipper, he sees to be a fine, delicate green net. To find the section to which this belongs, read each numbered sentence at the beginning of the Key: 1 will not do, since the specimen is not spherical, crescentic, nor circular; 2 will not do, because the plant is not in long threads; 3 and 4 do not describe it, because it is neither star-shaped nor formed of oval cells with two bristles on each end; but 5 calls for a green net often visible to the naked eye, which describes the specimen, giving the name of its genus, *Hydrodíctyon*, and referring the student to the Algæ, Section III, of this chapter. After using this preliminary Key for a few times, he will be able to decide, at a glance through the microscope, to which section his specimen belongs.

Key to Desmids, Diatoms, and Fresh-water Algæ

1. Plants formed of a single cell, crescentic, oblong and constricted, barrel-shaped, boat-shaped, elliptical, linear, sigmoid, undulate, spherical, or circular and flattened; cells sometimes arranged side by side in long ribbons, seldom end to end; color green or golden-brown (*a*).
2. Plants formed of many cells arranged end to end in long threads; coloring matter usually green, often in spiral bands or other patterns on the cell-wall (*d*).
3. Plants formed of several green cells grouped to form a flat disc, with from six to many short, blunt, star-like points; floating free. *Pediástrum*, (*Algæ, III*).
4. Plants formed of from two to eight, narrowly-oval, green cells placed side by side, each terminal cell with two often curved, colorless bristles; floating free. *Scenedésmus*, (*Algæ, III*).
5. Plants forming a green net visible to the naked eye. *Hydrodíctyon*, (*Algæ, III*).

a. Color green, the plant a floating, hollow sphere. *Vólvox*, (*Algæ, III*).
a. Color green, the plant not a hollow sphere (*b*).
a. Color golden-brown (*c*).
b. Cell-wall smooth, rough, warty, or spine-bearing, not silicious, but soft and flexible; always floating freely, never growing on stems permanently adherent to other objects, but sometimes attached side by side to form long bands or ribbons; a vacuole with swarming granules often present in each end. (*Dêsmids, I.*)
c. Cell-wall marked transversely, often also longitudinally, by lines, smooth bands, or dots; cell-wall hard, brittle, and silicious; floating freely, or growing on colorless stems permanently attached to other objects. (*Diatoms, II.*)
d. Plants forming cloud-like clusters, long streamers, or scum-like floating masses visible to the naked eye; color bright green or olive, sometimes almost black; the cells under the microscope united end to end to form long, sometimes branching filaments. (*Algæ, III.*)

I. DESMIDS

As the Desmids are singly invisible to the naked eye, the student can know what he has gathered only after reaching home, except in those rare instances in which the little plants have become congregated together in such quantities that a good pocket-lens will show their forms. The writer has more than once found *Clostêrium* in this profusion, but never any other.

The early spring, as early as the middle of March or the first of April, in the writer's locality (central New Jersey), is perhaps the best time of the year in which to gather them, or indeed any of the Algæ. At that time, all these plants seem to be more vigorous, and their vital functions to be performed more actively. The observer is then almost sure to see some of them in conjugation, or the union of two separate cells, and, it may be, the formation of the spores. This spore-

formation, however, is more frequently seen in the thread-like Algæ than in the single-celled Desmids.

There are more than four hundred known species of Desmids in this country. Perhaps an undue proportion has been included in the following list, but Nature offers them so freely and abundantly, they are so attractive, that they must be their own excuse.

The Rev. Francis Wolle, in his monograph on the Desmids, in reference to their preservation unmounted, so that they may be studied as temporary preparations, says, that "A few drops of carbolic acid in each phial, just enough to make its presence perceptible, will preserve the contents for months or even years from deterioration; the green coloring matter (chlorophyl) may fade, but this, in the case of the Desmids, is of little importance; nevertheless, when practicable, always examine the material when fresh. When dried on paper for the herbarium, the specimens can still, after being moistened with water, be microscopically examined, but not with the best results."

The following Key to the genera is to be used as directed for the "Key to the Desmids, Diatoms and Fresh-water Algæ," except that when the name of the genus has been found, the reader should refer to the paragraph, on a subsequent page, headed by that name, where he will find one or more species described and figured. If he has a green, half-moon-shaped plant under the microscope, to learn its name let him turn to this Key, the second line of which describes it, since it is not in ribbons nor bands; he should then refer to the lines headed by *d*, the first one of which describes the plant as a "cell more or less crescent-shaped," and gives the generic name *Closterium*, 6 being the number of the paragraph further on in this section of the chapter, where several species are noticed.

The reader may sometimes have difficulty in deciding whether or not a jelly-like sheath is present, as it is often so colorless and so faint that it is almost invisible, unless the light is specially directed by the manipulation of the mirror,

so as to cast a narrow line of shadow, on one edge of the envelope.

Again it is frequently absent by reason of the age of the plant, as the young growth appears to secrete it abundantly, but when for any reason, it has been lost, the more mature plant cannot, or at least does not, reproduce it. When a description, therefore, calls for a jelly-like sheath, the reader will probably be safe in assuming that it has been present, but has now melted away, unless it becomes visible after careful examination. Sometimes it is clearly outlined by numerous minute particles of extraneous matters adherent to the surface.

To determine the question may at first be somewhat troublesome, yet I do not recall an instance in which there was not some trace of the jelly-like sheath in the form of a faintly marked contour line on each side of the band, or as fine short, hair-like threads springing at right angles from the cell wall.

Key to Genera of Desmids

1. In ribbons or narrow bands (*a*).
2. Not in ribbons nor bands (*d*).

a. In a transparent, jelly-like sheath (*b*).
a. Not in a jelly-like sheath (*c*).
b. Each cell with two teeth on each narrow end. *Didymóprium*, 1.
b. Each cell deeply divided almost into two parts. *Sphærozósma*, 2.
b. Each cell without teeth and not divided. *Hyalothéca*, 3.
c. Cells barrel-shaped, the band not twisted. *Bambusína*, 4.
c. Cells not barrel-shaped, the band twisted. *Desmídium*, 5.
d. Cells more or less crescent-shaped. *Clostérium*, 6.
d. Cell cylindrical, spindle-shaped, hour-glass, or dumb-bell shaped (*f*).
d. Cell flattened, oblong, circular; often divided into arms (*e*).

e. Mostly circular or broadly elliptical; often cut and divided by narrow clefts and depressions; marginal teeth usually sharp. *Micrastérias*, 7.

e. Mostly oblong or elliptical; margin wavy, the depressions rounded; a central notch always present on each end. *Euástrum*, 8.

f. Cell constricted in the middle; no arms nor sharp spines (*g*).

f. Cell constricted in the middle; with arms or sharp spines (*h*).

f. Cell not constricted in the middle; no arms nor sharp spines (*i*).

g. Ends notched; cell cylindrical. *Tetmémorus*, 9.

g. Ends not notched; cell cylindrical. *Docídium*, 10.

g. Ends not notched; cell more or less dumb-bell or hour-glass shaped (*l*).

h. Arms, three or more, radiating; tipped by one or more points. *Staurástrum*, 12.

h. Arms none; spines four, two on each end. *Arthrodésmus*, 14.

h. Arms none; spines several, on the edges; a rounded, truncate, or denticulate tubercle near the center of each semi-cell. *Xanthídium*, 13.

i. Chlorophyl in a spiral band; cell cylindrical. *Spirotænia*, 15.

i. Chlorophyl not in a spiral band; cell cylindrical (*k*).

k. Surface roughened by oblong often tooth-like elevations. *Triplóceras*, 16.

k. Surface smooth; ends rounded, neither divided nor notched. *Peníum*, 17.

l. End view with from three to six or more angles (*m*).

l. End view not angular; margins smooth, dentate, or crenate, without spines; ends, always entire, never notched. *Cosmárium*, 11.

m. Angles obtuse, acute, or with horn-like prolongations. *Staurástrum*, 12.

1. Didymóprium

Each cell in the band longer than broad; two rounded or angular teeth on each narrow end; case or sheath distinct, colorless. *D. Grevíllii,* Fig. 17.

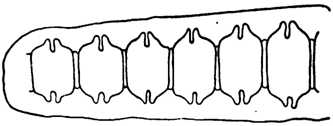


Fig. 17.—Didymórpium Grevíllii.

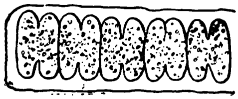


Fig. 18.—Sphærozósma púlchrum.

2. Sphærozósma

Each cell in the band about twice as broad as long, divided on both ends almost to the middle; sheath large, colorless, often absent. Five cells are shown in the figure. *S. púlchrum,* Fig. 18.

3. Hyalothéca

The ribbons are often very long; the narrow ends of each cell are sometimes slightly constricted, as shown in the lower part of the figure, but the depression is never deep enough to form teeth; sheath colorless; end view disc-like. *H. dissíliens,* Fig. 19.

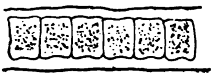


Fig. 19.—Hyalothéca dissíliens.

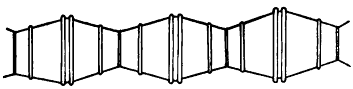


Fig. 20.—Bambusína Brebissónii.

4. Bambusína

The cells in form somewhat resemble barrels or casks joined together end to end, with two narrow hoop-like elevations around the middle of each. *B. Brebissónii,* Fig. 20.

5. Desmidíum

The twisted appearance of the band is due to the fact that the cells are triangular, as máy sometimes be seen when

they break apart and turn over on end, but the three angles are not all in the same line, each cell being slightly rotated laterally. When the side of the band is looked at, it is these angles that are seen, like a dark, oblique or zigzag line traversing the ribbon. Each cell is slightly toothed on both the narrow ends. Common. *D. Swártzii*, FIG. 21.

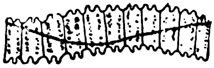


FIG. 21.—Desmídium Swartzii.

6. CLOSTÉRIUM (FIGS. 22 to 31)

All the species of this genus are more or less crescent-shaped, some being more curved than others, but none having exactly straight sides.

Near each end of almost every one is visible a clear, apparently circular vacuole containing many small, dark, swarming granules. These have already been referred to, as has the movement of the protoplasm between the cell-wall and the layer of green coloring-matter. *Closterium* is the only Desmid in which this cyclósis can be seen easily, if it ever occurs in others.

This protoplasmic circulation in *Closterium* is one of its great attractions, one of its charming features that is always worth searching for, although to see it well demands a moderately high power, a $\frac{1}{8}$-inch objective, for instance, or a higher power. The movement is fascinating, and the sudden and unexpected action of the granules that float in the protoplasmic tide, is astonishing. How the currents are produced, or why they exist, no human being knows. Theories on the subject are plentiful, but theories in such a case are difficult to prove.

The apparently circular vacuoles, or spaces, at the extremities of *Closterium*, are clear, transparent, colorless. They are always present in vigorous specimens, large and conspicuous in some, small in others, but always present when the plant is in good condition. How these vacuoles are maintained, why they are only at the ends of the cell, why they are always globular, why they do not float in the general

protoplasmic cyclosis, is not known. They contain a cluster of crystalline granules that are always, when the plant is in a healthy condition, dancing, quivering, trembling, in a way that is sure to attract and to hold the attention.

These crystals are flattened, and in outline are "diamond-shaped," or rhomboidal. They occasionally leave the vacuole, and pass into the general protoplasmic circulation. I have seen three thus pass out at apparently the same place in the vacuole.

There are thirty-five species in the genus. The following are some of the commonest. The convex margin is the "back," the concave border the "ventrum."

Key to Species of Clostérium

1. Ends not lengthened into a colorless beak (*a*).
2. Ends lengthened into a colorless beak (*f*).
   a. Back slightly convex, the whole cell but slightly curved (*b*).
   a. Back strongly convex; ventrum nearly straight (*c*).

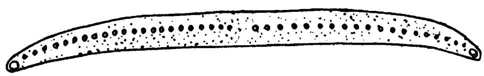


FIG. 22.—Clostérium lineátum.

a Back strongly convex; ventrum strongly concave, with a central enlargement (*d*).
a. Back strongly convex; ventrum without a central enlargement (*e*).
b. Ventrum nearly straight; vacuoles remote from the rounded ends; fifteen or twenty chlorophyl globules

FIG. 23.—Clostérium juncidum.

in a central longitudinal row in each semi-cell; diameter 24–36μ; surface striated. *C. lineátum*, FIG. 22.
b. Ventrum nearly straight; body tapering toward the rounded, sometimes curved, ends; vacuoles small, often scarcely visible; diameter 11–12μ. *C. júncidum*, FIG. 23.

b. Ventrum and back equally curved; ends tapering; from ten to fourteen chlorophyl globules in a central, longitudinal row in each semi-cell; vacuoles very small. *C. aceróśum*, FIG. 24.

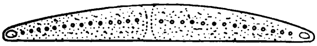


FIG. 24.—Clostérium aceróśum.

c. Ends rounded; chlorophyl often arranged in narrow, longitudinal bands; chlorophyl globules numerous; vacuoles near the ends; cell smooth, very large; diameter 80–110μ. *C. Lúnula*, FIG. 25.

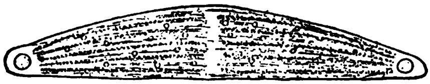


FIG. 25.—Clostérium Lunula.

d. Ends rounded; chlorophyl often arranged in narrow, longitudinal bands; chlorophyl globules often numerous; vacuoles close to the ends; cell large; diameter 75–110μ. *C. Ehrenbérgii*, FIG. 26.

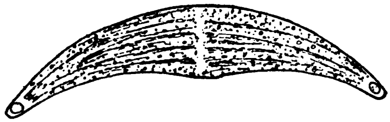


FIG. 26.—Clostérium Ehrenbergii.

e. Large, crescent-shaped; center broad; ends acute; vacuoles small; diameter 25–28μ. *C. acumináłum*, Fig. 27.

e. Small, crescent-shaped, sometimes semi-circular; distance between the ends about ten times the central diameter; center narrow; vacuoles indistinct; diameter 16–20μ. *C. Diánæ*, FIG. 28.

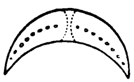


FIG. 27.—Clostérium acumináłum.

FIG. 28.—Clostérium Diánæ.

FIG. 29.—Clostérium Vénus.

e. Very small, crescent-shaped; from eight to twelve times as long as broad; center narrow; ends sharp; vacuoles distinct; diameter 8–10μ. *C. Vénus*, FIG. 29.

f. Each beak about as long as the green body, sometimes shorter; whole cell slightly curved, finely striate; vacuoles usually indistinct; diameter 23–40μ. *C. rostrâtum*, FIG. 30.

FIG. 30.—Clostérium rostrâtum.

f. Each beak exceedingly fine, longer than the spindle-shaped green body, the tips alone curved; diameter 10–11μ. *C. setáceum*, FIG. 31.

FIG. 31.—Clostérium setáceum.

7. MICRASTÉRIAS (FIGS. 32 to 39)

Each *Micrastérias* is incompletely divided across the middle into two equal and similar halves, or semi-cells, by a deep fissure, the sides of which may be either close together or somewhat separated. The margins of both semi-cells are much incised and notched, but both in the same way, the description of one-half, applying equally well to the other. There are more than forty species in the genus. The reader must expect to find many forms not included in this list, which contains only some of the most common in the writer's vicinity.

Species of Micrastérias

1. More or less circular in outline (*a*).
2. Not circular; divided into radiating arms (*b*).
3. Not circular; not divided into arms; central sinus gaping (*c*).

a. Each semi-cell divided by four deep cuts into one terminal and four side-lobes; each side-lobe divided by a shorter incision into two sections; each section by a still shorter cut divided into two divisions; each division by a yet shorter cut divided into two parts, and each part with two teeth. Desmid very large,

often measuring $\frac{1}{125}$ inch (200μ) in diameter. *M. radiósa*, FIG. 32.

a. Each semi-cell divided by four incisions into one end-lobe and four side-lobes; each side-lobe divided by a shorter cut into two parts; each part with two teeth. Each basal lobe, that is, the lobe immediately next to the long, transverse incision that divides the cell into the two semi-cells, has four subdivisions; each lateral lobe has eight. End lobes often dentate.

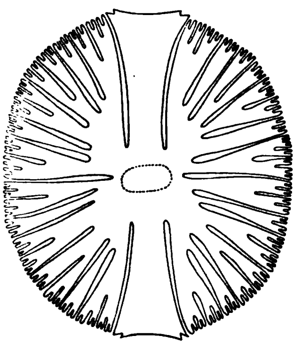


FIG 32.—Micrastérias radiósa.

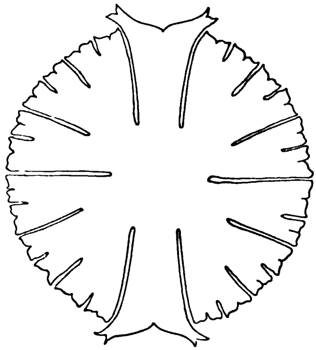


FIG. 33.—Micrastérias rotáta.

This beautiful Desmid is often larger than *M. radiósa*, measuring $\frac{1}{100}$ inch (250μ) in diameter. It is one of the most abundant species of the genus in the writer's locality. *M. rotáta*.

Another species, also happily rather common, so closely resembles *M. rotáta* that the one may be easily mistaken for the other. This is *M. fimbriáta*. The extreme margin of each ultimate subdivision of *M. rotáta*, while rather acutely pointed, is yet not distinctly toothed. This part in *M. fimbriáta* is plainly and even conspicuously dentate, each tooth sharply pointed, the two teeth on each subdivision frequently, not always, curving away from each other, giving the Desmid a beautiful appearance, and making it even more attractive than *M. radiósa*. Furthermore, *M. fimbriáta* often has a row of minute spines on each side of the end lobe, and sometimes

on each side of the lateral lobes. These are not constantly present, but when they are visible on a *Micrasterias* resembling *radiósa*, the species, whatever it may be, is not *radiósa*, but in all probability is *fimbriáta*.

These spines are small and easily overlooked, unless the observer have his sharpest eye at work, and "all his wits about him." The entire genus is so beautiful, that it is well to be sure of the species, when that is possible.

a. Each semi-cell divided by two incisions into one end-lobe and two side-lobes; each side-lobe by a shorter cut into two parts, and each part with two short teeth. End-lobes broad, often with two small teeth on each end. *M. truncáta*, FIG. 34.

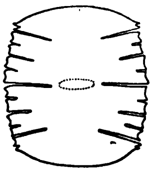


FIG. 34.—Micrastérias truncáta.

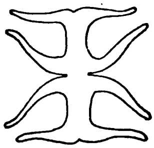


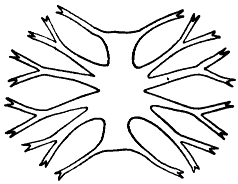
FIG. 35.—Micrastérias arcuáta.

b. Each semi-cell divided by deep rounded depressions into four tapering, slightly curved arms, the Desmid having eight undivided arms; diameter 90–110μ. *M. arcuáta*, FIG. 35.

This so closely resembles *Micrasterias expánsa* found in the same places, that the one is as likely as not to be mistaken for the other. The differences are so slight that the two are probably the same species, but the diameter of *Micrasterias arcuáta* (FIG. 35), is from 90 to 110 microns, that of *M. expánsa* about 75 microns. The apices of *M. expánsa* are often tipped by a "mucro," a short, sharp, abrupt point.

b. Each semi-cell divided by two acute depressions into one end-lobe and two side-lobes; each side-lobe divided by an acute depression into two short parts; each part divided by an acute depression into two short arms,

and each arm with two teeth; arms of the end-lobes each with two teeth; the Desmid has twenty short arms. *M. dichótoma*, FIG. 36.



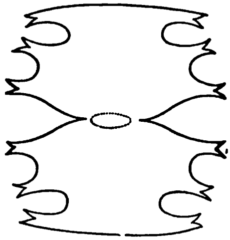
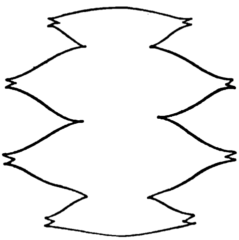


FIG. 36.—Micrastérias dichótoma. FIG. 37.—Micrastérias Kitchéllii.

c. Divided into one end-lobe and two side-lobes (*d*).

d. Side-lobes divided by a shallow notch into two parts extending beyond the end-lobes, each part with two teeth; length 125μ. *M. Kitchéllii*, FIG. 37.

d. Side-lobes not divided into two parts, but extending beyond the end-lobes; terminal lobes sometimes notched laterally, as shown in the figure, sometimes not; diameter 150–160μ. *M. óscitans*, FIG. 38.



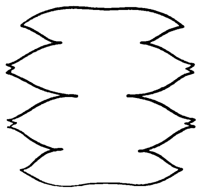


FIG. 38.—Micrastérias óscitans. FIG. 39.—Micrastérias láticeps.

d. Side-lobes not divided into two parts, not extending beyond the end-lobes; diameter 160–212μ. *M. láticeps*, FIG. 39.

8. EUÁSTRUM (FIGS. 40, 41, 42)

Euástrum is almost divided into two halves by a central constriction or sinus, but the cell outline is never circular

as in *Micrastèrias;* the margins are wavy but never sharply toothed. Each end always shows a single, central notch or deep depression. There are forty species.

1. Each half-cell oblong; an end-lobe present in both halves, formed by a short rounded incision on each side; diameter 68–82μ; surface smooth. *E. crássum*, FIG. 40.

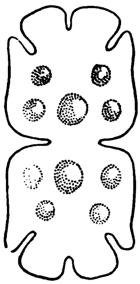


FIG. 40.—Euástrum crássum.

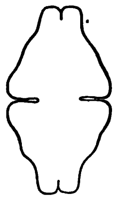


FIG. 41.—Euástrum didélta.

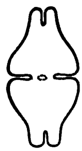


FIG. 42.—Euástrum ansátum.

2. Each half-cell somewhat triangular; without distinct end-lobe (*a*).
   a. Sides wavy, gradually expanding towards the central incision; surface punctate; diameter 22–25μ, length 45–54μ. *E. didélta*, FIG. 41.
   a. Sides hardly wavy, suddenly expanding towards the central incision; small; surface punctate. *E. ansátum*, FIG. 42.

9. TETMÉMORUS (FIGS. 43, 44)

1. Widest in the middle, the ends tapering; the entire surface punctate, that is, irregularly dotted. It is this that

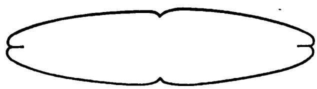


FIG. 43.—Tetmémorus granulatus.

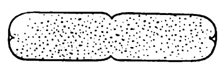


FIG. 44.—Tetmémorus Brebissónii.

gives the plant its specific name. Diameter 38–50μ. *T. granulátus*, FIG. 43.

2. Not widest in the middle, the ends not tapering; surface striately punctate; diameter 18–20μ. *T. Brebissónii*, FIG. 44.

10. DOCÍDIUM (FIGS. 45, 46)

1. A slight, rounded enlargement on each side of the central constriction; smooth; no terminal vacuoles; diameter 14–22 microns. *D. Báculum*, FIG. 45.

FIG. 45.—Docidium Báculum.

FIG. 46.—Docidium crenulátum.

2. Two or several small enlargements on each side of the central constriction, give the margins a wavy outline; coarsely punctate; from 8 to 16 times longer than broad; diameter 40–60μ. *D. crenulátum*, FIG. 46.

11. COSMÁRIUM (FIGS. 47, 48, 49, 50)

The ends of *Cosmárium* are never notched nor incised. The absence of this terminal depression, or notch, from *Cosmárium*, makes the Desmid easily distinguishable from *Euástrum* in which this emargination is always present. These Desmids may be, and often are, rough or warty. There are about one hundred species. The following are common:

1. Surface smooth; cell less than twice as long as broad; the two semi-cells evenly rounded, nearly semicircular; diameter, 60–100μ. *C. Rálfsii*, FIG. 47.

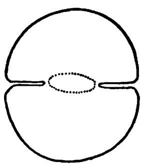


FIG. 47.—Cosmárium Rálfsii.

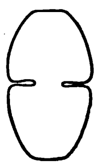


FIG. 48.—Cosmárium pyramidátum.

2. Surface punctate; cell about twice as long as broad; the margins of each semi-cell slightly sloping toward the flattened ends; diameter 50–85μ. *C. pyramidátum*, FIG. 48.

3. Surface roughened by rounded, pearly elevations; ends broadly rounded; diameter 25–50μ. *C. margaritiférum*, FIG. 49.

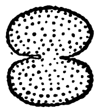


FIG. 49.—Cosmárium margaritiferum.

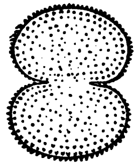


FIG. 50.—Cosmárium Brebissónii.

4. Surface roughened by small, sharp-pointed, conical elevations; diameter 45–65μ. *C. Brebissónii*, FIG. 50.

12. STAURÁSTRUM (FIGS. 51, 52, 53, 54)

In front view, or in the position in which the Desmids usually lie when undisturbed, *Staurástrum* often resembles *Cosmárium*, but in end view it is always angular. It is sometimes rather troublesome to get *Staurástrum*, or any other Desmid, tilted up on end so that it may be examined in that position, but in a moderately deep cell, with considerable

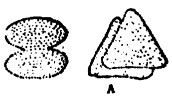


FIG. 51.—Staurástrum punctulátum.

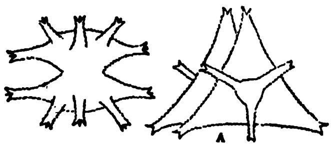


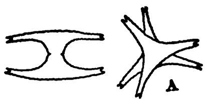
FIG. 52.—Staurástrum furcígerum

water, and under a low-power objective, it can usually be turned over by gently tapping and pressing the cover-glass with a needle.

Staurástrum is a large genus, containing about one hundred and twenty species.

In each of the succeeding figures *A* represents the end-view of the Desmid.

1. Cell dumb-bell shaped; without arms; end view triangular; surface roughened by small elevations. *St. punctulátum*, FIG. 51.
2. Cell not dumb-bell shaped; with arms (*a*).
   a. Cell triangular in end-view, the angles toothed; arms in a cluster of about three on the end of the cell, their ends toothed; surface granular in transverse lines; diameter 50–62μ. *St. furcígerum*, FIG. 52.
   a. Cell triangular in end-view, the angles prolonged as narrow arms, the ends of which are three-toothed; surface roughened; diameter 40–50μ. *St. grácile*, FIG. 53.



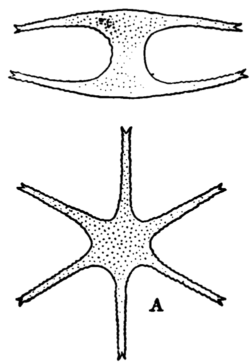


FIG. 53.—Staurástrum grácile. FIG. 54.—Staurástrum macrócerum.

   a. Cell in end-view with six or seven radiating arms, their ends three-toothed; surface granular; diameter 150–180μ. *St. macrócerum*, FIG. 54.

13. XANTHÍDIUM (FIGS. 55, 56)

The cells bear near each end a prominence or tubercle, that may be rounded and smooth, truncate, or apparently encircled by small beads.

1. Cell about twice as long as broad; spines short, their ends irregularly toothed; tubercles circular, beaded. This is the only species with toothed spines. *X. armátum*, FIG. 55.

2. Cell not twice as long as wide; each half-cell somewhat kidney-shaped; spines in four or six pairs on each semi-cell, not divided nor toothed, but often curved; tubercle central, small, conical, not beaded. *X. antilopæum*, FIG. 56.

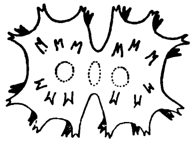


FIG. 55.—Xanthidium armátum.

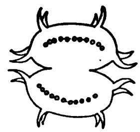


FIG. 56.—Xanthidium antilopæum.

14. ARTHRODÉSMUS (FIGS. 57, 58)

1. Spines on the same side curving or spreading from each other; surface smooth. *A. íncus*, FIG. 57.

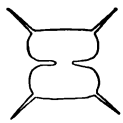


FIG. 57.—Arthrodésmus incus.

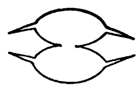


FIG. 58.—Arthrodésmus convérgens.

2. Spines on the same side curving toward each other; surface smooth. *A. convérgens*, FIG. 58.

15. SPIROTÆNIA

Cell somewhat spindle-shaped; ends rounded; spiral band closely wound; diameter 18–25μ. *S. condensáta*, FIG. 59.

FIG. 59.—Spirotænia condensáta.

16. TRIPLÓCERAS

Surface roughened by small projections arranged in rows around the cell, their tips notched or finely toothed; cell from

twelve to twenty times as long as broad. *T. verticillátum*, FIG. 60. This is classed by some authorities on the subject, in the genus *Docidium*, and is therefore called *Docidium verticillátum*.

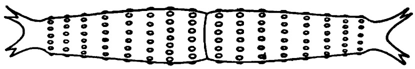


FIG. 60.—Triplóceras verticillátum.

Ends with three bidentate processes. Diameter 38–45μ.

17. PENÍUM

Cylindrical; ends rounded; surface smooth; often found in quantity so great as to form an almost continuous film. Diameter about 17 microns. *P. Brebissónii*, FIG. 61.

If it is desired to preserve any of the Desmids or the Algæ, the following solution will be found to be an excellent medium. In it the plants retain their green color for a long time, and the cell-contents have less tendency to shrink from the cell-wall than with any other of the many media often recommended. Any druggist can make the solution. It is composed as follows: Camphorated water and distilled water, of each, 50 grammes; glacial acetic acid, 0.5 gramme; crystallized chloride of copper and crystallized nitrate of copper, of each, 2 grammes; dissolve and filter. The solution was originally devised by M. Petit, a French microscopist.

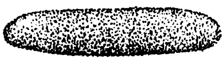


FIG. 61.—Peníum Brebissónii.

The plants should be placed in a cell made of shellac, a few drops of this preservative copper-solution added, and the cover fastened down with shellac. If any other cement, except perhaps rubber-cement, is used with this solution, it will inevitably run under the cover and ruin the preparation.

The Rev. Francis Wolle in his monograph on the "Desmids of the United States and List of American Pediastrums," says that a few drops of carbolic acid added to each phial containing the plants, just enough to make its presence perceptible, will

preserve the contents for months and even for years from deterioration; the green coloring matter may fade, but this, in the case of the Desmids, is of little importance. The contour of the cells will remain unchanged. It is the form rather than the cell contents that is important in their identification and study.

If the reader should find the Desmids so pleasing that he desires to study them, rather than to learn the names and the appearance of a few of the commonest as here given, he should refer to the Rev. Francis Wolle's monograph, and to the writer's "Fresh-water Algæ and the Desmidieæ of the United States," the latter being an extended, mostly artificial Key to the genera and the species of these attractive plants, founded on Wolle's classification.

II. DIATOMS

For a long time there was much discussion as to the animal or vegetable nature of the Diatoms. That they are plants is now the general belief. Their peculiar motion was one great reason for classing them among the animals, although some undoubted plants have even a more rapid movement.

No class of microscopic objects, except, perhaps, the Infusoria, is so abundant. No ditch or pond is without them. No pool is too small to harbor them; even a depression made by a cow's hoof in a wet meadow soon becomes a home for them. They will probably form some of the first things to attract the attention of the novice in the use of the microscope.

Their shape is as varied as their number is great. Their hard and glass-like surface or external skeleton is beautifully lined and dotted and sculptured in delicate tracery. Most plants are comparatively soft, but the Diatoms are noteworthy for the hard case that encloses the semi-fluid, yellowish-brown contents, a case that is indestructible. It may be heated to redness, it may be boiled in strong acids and in alkalies, and at the end be as it was before, as gracefully formed and as beautifully marked. Properly to study the surface markings, the Diatoms should be treated by some method to destroy

the coloring matter often obscuring these geometrical designs, which, for many purposes, make them so highly valued. For the beginner, however, who desires only to recognize a Diatom when he meets with one in the field of his microscope, and to learn its name, if possible, such preparation is unnecessary.

These plants are also peculiar in their structure. In this they have often been compared to a pill-box. The Diatom is formed of two parts called valves, one of which may be likened to the pill-box proper, and the other to the lid, since it slips over the upright edge of the lower and usually younger valve.

The entire box-like Diatom is called the frustule. The surfaces of the upper and lower valves are usually marked alike, and usually but not always shaped alike, and are called the sides. When the frustule happens to be turned so that the narrowest part, or that part corresponding to the thickness or height of the pill-box, and called the front, is toward the observer, the shape is so different from that of the valves as often to puzzle the observer. If in doubt about the position, gently tap the cover-glass with a needle, when the frustule will generally roll over on its broad side. All this seems somewhat bewildering at first, but there will be no difficulty if it is borne in mind that the thickness of the pill-box corresponds to the *front* of the *frustule*, and the broad surfaces of the lid and the bottom to the *sides* of the *valves*.

In addition to the valves which together form the frustule, there is another part, of which less is heard among diatomists, although it is important, and is itself sometimes striated or sculptured. This corresponds to that portion of the pill-box remaining after the top and the bottom have been removed. The part of the box corresponding to the height or thickness of the diatom-frustule, is called, in the Diatom, the hoop. After the frustule has been cleaned and the valves separated, the hoop may often be seen lying in the mounting medium, frequently set up on its edge, and still retaining somewhat of the contour of the original frustule. These hoops

are sometimes rather puzzling when first found in a mounted preparation of Diatoms, as they generally resemble very narrow, curved or circular filaments that may lead the observer to suppose that some extraneous and foreign object has been accidentally included in the mount.

Besides the ordinary markings on the valves—that is, the transverse lines which are sometimes so coarse that they are called ribs—each valve frequently bears a line or a narrow smooth band down the middle, named the raphé, while at each end and at the center there is often a small rounded spot resembling a circular space, but being in reality a thickening, and called the nodule.

Immense beds of fossil frustules and valves are found in many parts of the world, especially in our own country. In Maryland and in New Jersey, diatomaceous earth is obtained containing exquisite forms. In Virginia a certain deposit is especially renowned, since it is eighteen feet thick and underlies the city of Richmond. This has afforded the student some of the rarest and most valued frustules, or valves, for the frustule, before its sculpturing can be properly studied, must be separated into its two valves.

To have produced such a mass, the Diatoms must have existed in incalculable numbers in a great body of water, where, undisturbed for a long time, they died and sank to the bottom year after year, their skeletons accumulating as others continued to fall. To appreciate the probable length of time during which they existed with nothing to interrupt their peaceful life, as well as the number of Diatoms needed to make such a deposit, it is only necessary to know that a single frustule is seldom thicker than the one ten-thousandth part of an inch, or 2.5 microns.

At the present day, living Diatoms are often found in so large numbers that they form a yellowish-brown film on the mud in shallow water. In such cases it is no trouble to skim them up and so to gather them. Usually, however, the reader will first see them floating freely about his slide, or attached to various plants. Few are visible to the naked eye, except

when collected in great masses, and then only as brownish patches. The individual valves are seldom seen without the microscope, and in such instances only by the most acute and best educated eye.

They are difficult to study and to identify. To examine them properly demands the highest-power objectives of the best construction, and a skill in the use of the microscope and accessory optical apparatus, not at the beginner's command.

Much has been written about them, but the literature of the subject is so widely scattered through the scientific magazines, that only those that make a special study of the subject can hope to have it in their libraries. But the beginner need not despair. With ease he can learn to recognize a Diatom whenever seen, and to know the names of the commonest forms. This is all that he will care to learn at first. Yet he will find it a satisfaction to be able to say to a friend: "That is a Diatom," and to explain its box-like structure.

The following Key has been made to assist the reader in ascertaining the names of a few of the commonest fresh-water forms. It is impossible to include even a tithe of the plants, and the microscopist will surely find many not mentioned in the succeeding list, but by the brownish color, the movements common to so many, and the hard, dotted, striated, or otherwise sculptured valves, he may readily know them to be members of the *Diatomáceæ*, after he has observed and recognized one. More than this he can scarcely hope to do.

The golden-brown coloring matter will often be seen contracted to a narrow strip, or to a spot at each end, while frequently the frustule will be entirely colorless. Diatoms are the favorite food of many microscopic animals, which absorb the cell-contents, leaving the hard and indigestible valves colorless, but otherwise unchanged.

Key to Genera of Diatoms

1. Growing in bands or ribbons (*a*).
2. Growing on colorless stems or in a jelly-tube (*c*).
3. Growing with their concave sides attached to other plants (*e*).

4. Free-swimming (*f*).
   a. Band curved or coiled. *Merídion*, 1.
   a. Band zigzag; frustules attached together by the corners. *Diátoma*, 2.
   a. Band uneven; frustules long, narrow, rapidly sliding on one another. *Bacillária*, 3.
   a. Band straight, or nearly so; edges even; frustules motionless (*b*).
   b. Each frustule six times as long as broad. *Fragilária*, 4.
   b. Each frustule twice as long as broad. *Himantídium*, 5.
   c. In a narrow jelly-tube; valves boat-shaped. *Encyonēma*, 6.
   c. On the ends of colorless stems (*d*).
   d. Valves boat-shaped. *Cocconēma*, 7.
   d. Valves wedge-shaped. *Gomphonēma*, 8.
   e. Valve six to seven times as long as broad; ribs conspicuous, oblique. *Epithēmia*, 9.
   e. Valve oval, nearly as long as broad. *Cocconēis*, 10.
   f. Valve not curved nor S-shaped (*g*).
   f. Valve in side view arched, the convex margins scalloped. *Eunótia*, 11.
   f. Valve long S-shaped. *Pleurosígma*, 12.
   f. Valve boat-shaped or obovate, the ribs sub-parallel, conspicuous. *Surirēlla*, 13.
   f. Valve boat-shaped; ribs none. *Navícula*, 14.
   g. Valve strongly ribbed transversely; a nodule at each end and in the center. *Pinnulária*, 15.
   g. Valve not ribbed; with a central longitudinal, and a transverse, smooth band, together forming a cross. *Stauronēis*, 16.

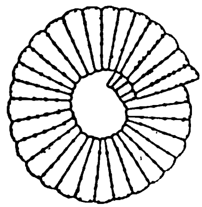


FIG. 62.—Merídion circuláre.

1. MERÍDION CIRCULÁRE (FIG. 62)

Valves wedge-shaped; transverse lines indistinct, except under a high power; bands spiral, often broken into small curved sections (FIG. 62). Common

2. DIÁTOMA VULGÁRE (FIG. 63)

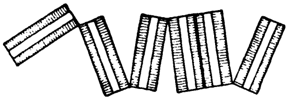


FIG. 63.—Diátoma vulgáre.

Frustules oblong, their four angles being right-angles; the band often attached to aquatic plants; easily separable into its component frustules (FIG. 63). Common.

3. BACILLÁRIA (FIG. 64)

Frustules long and narrow; united laterally; freely and rapidly sliding backward and forward over one another; colony free-swimming (FIG. 64).

This is probably one of the most interesting of the common fresh-water Diatoms, on account of its strange movements. When quiet, as it probably will be immediately after being placed on the slide, the band will somewhat resemble a row of fence-pickets lying in contact side by side. Suddenly each picket shoots forward until all are nearly end to end, the band becoming a long irregular line, when they quite as suddenly again close together. This alternate backward and forward gliding is continued until the Diatoms becomes apparently exhausted, or the oxygen in the water is consumed. What prevents one frustule from slipping off the end of the other is not known; at the cause of the entire frantic performance we can only guess.

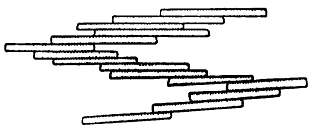


FIG. 64.—Bacillária.

All the species of the genus *Bacillária* are said to live in salt water or in brackish water, but the form that I have ventured to identify as a sweet-water variety of *B. paradóxa*, is not uncommon in fresh-water ponds in my vicinity in New Jersey.

4. FRAGILÁRIA CAPÚCINA (FIGS. 65 and 65*a*)

Frustules very narrow, never wedge-shaped; band long. FIG. 65 shows the ribbon of united frustules; FIG. 65*a* the

appearance of a single valve more highly magnified. The ends of the valves are somewhat wedge-shaped.

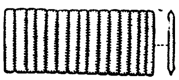


FIG. 65 and 65*a*.—Fragilaria capucina.

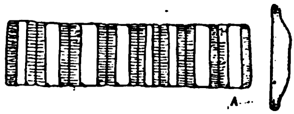


FIG. 66.—Himantidium pectinále.

5. HIMANTÍDIUM PECTINÁLE (FIG. 66)

Frustules much wider than the preceding; transverse lines distinct on both sides of a narrow, central and, to a low power, apparently smooth space (FIG. 66). *A* is the side view of a single frustule, more highly magnified.

I once found this Diatom so profusely developed on the margin of a little spot of marshy ground, that it might have been gathered by the teaspoonful.

6. ENCYONÉMA PARADÓXUM (FIG. 67)

The jelly-tubes are usually very slightly, if at all, branched.

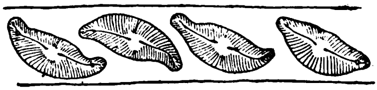


FIG. 67.—Encyonéma paradóxum.

The frustules are commonly arranged in a longitudinal series within the tubes, which are attached to other plants (FIG. 67).

7. COCCONÉMA LANCEOLÁTUM (FIGS. 68 and 68*a*)

Stems often much branched; attached to aquatic plants and to other submerged objects; frustules on the ends of the branches; in side view (valves) slightly curved, with a median longitudinal line having a nodule at each end and one in the center (FIG. 68). The frustules are often found floating freely. They are then usually seen in side view. FIG. 68*a* shows a single valve highly magnified.

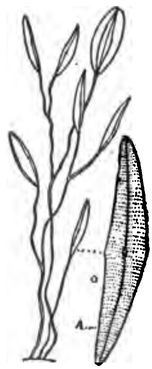


FIG. 68 and 68*a*.—Cocconéma lanceolátum.

8. Gomphonéma acuminátum (Fig. 69)

Stems often much branched, but frequently found unbranched; attached to other plants; frustules slightly swollen in the center; the narrow end of the wedge is attached to the stem (Fig. 69).

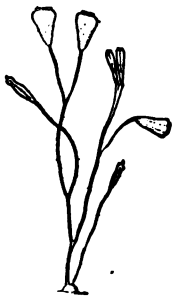


Fig. 69.—Gomphonéma acuminátum.

Fig. 70.—Epithémia turgida.

9. Epithémia túrgida (Fig. 70)

Valves curved or bent; transverse lines coarse and conspicuous (Fig. 70). Often found separated from its supporting plant, and floating freely.

10. Cocconéis pedículus (Fig. 71)

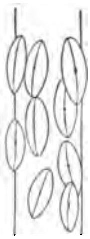


Fig. 71.—Cocconéis pediculus.

Valves oval, with a line (raphé) down the center and a small nodule in the middle; attached by one valve to aquatic plants, especially to the leaves of *Elodéa*. (Fig. 71.)

I have seen these Diatoms so profusely developed on a leaf of *Elodéa Canadénsis*, that they were in contact with one another by their margins, and one surface of the leaf bore fifteen thousand frustules, a *Cocconeis* mob.

11. EUNÓTIA TETRÁODON (FIG. 72)


FIG. 72.—Eunotia tetraodon.

Valves curved; a small nodule at each end of the concave margin; the convex border apparently scalloped, but in reality bearing four or more rounded ridges (FIG. 72).

12. PLEUROSÍGMA (FIG. 73)

Valves long S-shaped; widest in the middle and tapering to each end, one of which curves toward the right-hand side, the other toward the left-hand (FIG. 73). A narrow S-shaped line, the raphé, extends down the center of the valve with a nodule conspicuous in the middle only.


FIG. 73.—Pleurosigma.

There are nearly two hundred known species and varieties of this genus, most of which may be recognized by this peculiar and beautiful curvature of the sides, the word *Pleurosígma* meaning S-shaped sides.

The valves, under a comparatively high power, a good $\frac{1}{4}$ or $\frac{1}{5}$ inch, appear to be finely striated in three directions, transverse, and decussately oblique. These lines are remarkably close together, and demand for their resolution not only a fine objective, but careful manipulation of the light. This appearance, however, does not represent the true structure.

The valves are often used to test the good qualities of certain objectives. To the beginner, all the *Pleurosígmas* will probably appear to be smooth. The species most frequently used as a test is *P. angulátum*, a salt-water form.

13. SURIRÉLLA SPLÉNDIDA (FIG. 74)

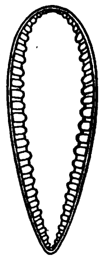


FIG. 74.—Surirélla spléndida.

The valves are obovate in form, with transverse ribs large and conspicuous, the spaces between them seeming to be lower than the edges of the valves, thus giving the latter the appearance of having a narrow wing around the margin (FIG. 74). The members of this genus are

also used as test-objects. The one most commonly employed, *Surirella gemma*, is a marine species.

S. splendida is frequently captured in the ponds near the author's home in New Jersey.

14. Navícula cuspidáta (Fig. 75)

Valves somewhat diamond-shaped, or rhombic; widest in the center, tapering with straight margins to each end; a straight line (raphé) down the middle with a central nodule (Fig. 75).

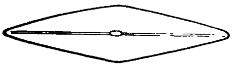


Fig. 75.—Navicula cuspidáta.

15. Pinnulária (Figs. 76 and 77)

1. Margins of the valves parallel, their ends and center somewhat inflated; transverse ribs large and conspicuous; a line (the raphé) down the middle, with a nodule at each end and at the center; frustule large. Common. *P. májor*, Fig. 76.

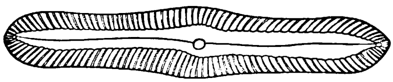


Fig. 76.—Pinnulária major.

Fig. 77.—Pinnularia viridis.

2. Margins of the valves slightly convex, the ends and the center not inflated; ribs large and conspicuous; a line (the raphé) down the middle, with a nodule at each end and one in the center; frustule smaller than the preceding. It is named *víridis*, as some one has said, probably because it is always brown. *P. víridis*, Fig. 77. This is one of the commonest of our fresh-water Diatoms.

Diatomists now class *Pinnularia* with *Navicula*, and call these forms *Navicula major* and *Navicula viridis*.

16. Stauronéis phœnocénteron (Fig. 78)

Valves widest in the middle; tapering with convexly curved margins to both ends; central and transverse bands smooth

and conspicuous. Common. (FIG. 78). The cruciform, smooth band is the characteristic by which it may at once be recognized.

For a collection of illustrations of the Diatoms of this country, the reader should refer to Wolle's "Diatomaceæ of North America, Illustrated with Twenty-three Hundred Figures."

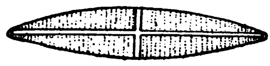


FIG 78.—Stauronéis phœnocénteron.

The book is preceded by a Key that leads to the genus, where, to learn the species, the reader is expected to refer to the numerous plates. There he will find the Diatom, if it be a form from North America.

III. FRESH-WATER ALGÆ

The Algæ often collect together and form green clouds in the water, or a scum-like growth on the surface. Frequently, however, the student will find isolated filaments under his microscope, and not know how they were placed there, or he will find single threads adherent to other aquatic objects that he may be examining.

The color of the visible masses is usually bright green; it may be brownish, if the plants are in fruit, or the natural tint of the individual Alga may be blue-green, brownish, purplish, or, when massed together, almost black.

Many species are coated with a mucous, slimy material that makes them slippery, and difficult to handle or to remove from the water, unless a dipper or a spoon be used, sometimes not even then.

They are seldom found in any abundance in deep water. They appear to prefer shallow ponds and slowly flowing streams, where they may have plenty of warmth and light. Few of the species are free-swimming. Many kinds appear in great patches that float on the water; others adhere to submerged leaves, stones, or sticks; some form feathery clusters of branching filaments; others surround themselves by little balls of

translucent jelly that are often found studding leaves of grass or other objects in the ponds.

The masses which thê Algæ in general form are usually composed of great numbers of long threads, commonly called filaments, and matted together, probably by their rapid growth, among other causes. Each filament is built up of many cells attached to one another by their narrow ends. The single filament is for convenience considered a single and entire plant.

The Algæ have no roots, although they may fasten themselves by one end to submerged objects. A few, single-celled terrestrial forms have minute branching filaments, that may be called rootlets, growing from them and penetrating the ground. (*Botrydium.*)

Some are simple, straight, or curved cellular threads; some give off branches which generally resemble the main plant or stem. Their color is usually some shade of green, although a few purplish and brownish ones are known.

The following have been partly described in the Key on a preceding page.

1. SCENEDÉSMUS (FIG. 79)

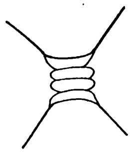


FIG. 79.—Scenedesmus caudátus.

The cells are usually four, attached together by their long sides. The spines or bristles on the narrow ends of the two terminal cells are curved or inclined away from each other. A spine sometimes grows from the middle of one of the central cells. The plant is common. *S. caudátus*, FIG. 79.

2. PEDIÁSTRUM (FIG. 80)

The green cells are usually so arranged as to leave narrow, colorless bands between them, and occasionally, in those species formed of a great number of adherent cells, several apparently empty, colorless spaces are scattered about the disc.

In the latter cases the marginal teeth, which are always colorless, are often numerous, but they are usually more or less conspicuously arranged in groups of two each. In the species here figured the marginal teeth are generally twelve in number. *P. Borydnum,* FIG. 80. There are about a dozen known species in this country. Most of them are not rare.

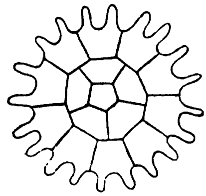


FIG. 80.—**Pediástrum Borydnum.**

The surface is often punctate, or covered with small granules. Some of the numerous species are probably only stages in the development of one or two only.

3. VÓLVOX

A small sphere continually in movement, rolling through the water in a graceful manner, its surface studded with green points. Under a low power it appears like a hollow globe, and the cause of the motion is a mystery; but the $\frac{1}{8}$ inch objective, when *Vólvox* moves slowly or rests, shows that each of the green points that together stud the surface bears two fine cilia, or little hairs that are continually vibrating, and lashing the water. It is from their vibrations that the *Vólvox* receives its rolling motion.

The deep-green balls often seen within the larger globe are young plants in different stages of development. When matured, the mother-globe is ruptured, and the young plants float out and roll away through the water, revolving there as they are often seen to do even before leaving the parent, and there leading an independent existence.

The water in some localities is, in June, so filled with these rolling globes that it is colored green by them, and when the collecting-bottle is held against the light they become visible to a sharp eye as small pale-green spheres. The diameter of a full-grown plant is about one-fiftieth of an inch. *V. globátor.*

They occur everywhere but are not common anywhere. In those localities where they usually exist they seem to

have periods of profusion and of deficiency. In a small and shallow but permanent pond where, several years ago, the writer found them literally and actually by the thousand, he has never since been able to discover a single specimen. This is not an instance of periodic deficiency, but of complete absence. Still, the rule seems to hold good for this country. In England the beautiful creatures seem to be more permanent denizens of shallow pools, and are more frequently collected.

They have had a varied experience with the systematists, or those scientific men that appear to be happy only when they are arranging the objects of Nature in classses and groups, for these pretty globes have been classified among the plants, then among the animals, and back and forth in a way that would have bewildered them perhaps, if they had been conscious of it, but certainly in a way to bewilder a reader that has tried to follow the changes to and fro, and tried to get the unfortunate things safely lodged in the one group or the other. At present they are said to be animals. Their latest investigator has so decided. By the time this book is out of the printer's hands, however, *Vólvox* may again be a plant.

It has been here referred to as a plant and included among the plants for convenience, the writer trusting to the explanations of its vicissitudes to impress the reader with the fact that, just now, *Vólvox* is said not to be a plant, although in fact no one knows what it really is. It is so close to the borderline between the animal and the vegetable that it may be both in one, or neither.

Those that assert that *Vólvox* is a vegetable, do so on account of its peculiar methods of reproduction, of which there are two, both of which are too complex to be more than casually referred to here.

Those that class it among the animals do so chiefly on account of the presence of one, sometimes of two, contractile vesicles, pulsating organs common to many microscopic animals, especially to the Infusoria (Chapter V), and the Rhizo-

pods (Chapter IV). This contractile vesicle usually appears to be a circular, almost colorless space, which at regular intervals contracts and entirely vanishes, only to reappear in the same form, generally in the same place, there again to resume its peculiar pulsating movements. Its function is supposed to be, in part, to receive the water swallowed by the animal with its food, and which must be discharged from the body after having circulated through the protoplasm. As the animal lives submerged, it must necessarily swallow much water with its submerged food.

I have had the good fortune to observe the actual ejection of the liquid contents from the contractile vesicle of an Infusorium. The animalcule was encompassed by a cloud of bacteria and of similar minute bodies and débris, through which, at every contraction of the vacuole, a narrow path was swept with a quick rush, as a passage might be made through the dust by the sudden blast from a bellows.

Volvox has as many contractile vesicles as it has green, lash-bearing bodies studding its surface, and at times two vesicles to each. These are colorless and exceedingly minute, but exceedingly active, snapping themselves into invisibility, and reappearing almost as suddenly and quickly. To see them is not an easy microscopical task. It is distinctly difficult, demanding a high-power objective of good quality, careful scrutiny, a slowly moving or quiescent *Volvox*, and a full supply of that patience for which a microscopist soon finds abundant use.

That contractile vesicles exist in *Volvox* is a fact, and if those scientists are right who say that the presence of such organs always indicates an animal, then is *Volvox* not a plant. If they are wrong, as they probably are, *Volvox* manifests no anxiety, but floats in its graceful curves, and remains as delicately beautiful and as carelessly free as if it had never excited a moment's interest or a moment's discussion.

A small, free-swimming Rotifer (Chapter VIII), *Hertwigia parasita*, lives as a parasite within the spheres of *Volvox globata*. It is said to occur frequently. I have not seen it.

4. HYDRODÍCTYON (FIG. 81).

A yellowish-green scum is sometimes seen on the water, which, when spread over the fingers, proves to be a net of delicate hexagonal meshes. It may grow to ten or twelve inches in length, and form floating masses several inches in thickness. The nets are composed of narrow, short, cylindrical cells, and under a low power, are remarkably beautiful. The figure shows a part of a net. *H. utriculátum*, FIG. 81.

FIG. 81.—Hydrodíctyon utriculátum.

In the writer's locality in New Jersey *Hydrodíctyon* occurs so profusely at times that it might be collected by the wheel-barrow load. It is not uncommon elsewhere.

The following is a Key only to those genera referred to in this book.

Key to Genera of Fresh-water Algæ

1. Color brownish-green, bluish, or olive (*a*).
2. Color pure green (*d*).
   - *a*. Filaments branched (*b*).
   - *a*. Filaments not branched (*c*).
   - *b*. Branches with many, whorled, moniliform threads; plant slippery. *Batrachospérmum*, 1.
   - *c*. Moniliform; plant with larger, scattered, spherical cells. *Anabæna*, 2.
   - *c*. Not moniliform; plant bluish green; twisting, bending, gliding. *Oscillária*, 3.
   - *d*. Green color in one or more spiral bands in each cell. *Spirogýra*, 4.
   - *d*. Green color in two star-shaped masses in each cell. *Zygnéma*, 5.
   - *d*. Green color not in patterns (*e*).
   - *e*. Terminal cells with a colorless, hair-like bristle (*f*).

e. Terminal cells without a bristle. *Vauchéria*, 6.
f. Forming small, green, visible, jelly-like masses. *Chætóphora*, 7.
f. Not forming jelly-like masses (*g*).
g. Cells of the branches green, those of the stem larger, colorless, but with a transverse green band. *Draparnáldia*, 8.
g. Cells of branches and stem green; bristles with a swollen base. *Bulbochæte*, 9.

1. Batrachospérmum (Fig. 82)

The plant often grows abundantly, attached to submerged objects, in springs, ditches, and ponds. It varies in length from an inch or less, to one or two feet, and in color may be bluish-green, brownish, or purplish. It is covered with a mucous substance that makes it an exasperating thing to take out of the water, as it is so slippery and so difficult to handle. It is much branched. The branches are formed of many short threads in whorls, each thread conspicuously beaded. The whorls of branches are often so close together that the entire plant, as it floats beneath the water, appears to be a string of little balls.

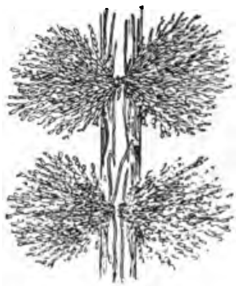


Fig. 82.—Batrachospérmum monilifórme.

Under the microscope each moniliform thread is usually seen to be terminated by a colorless hair-like bristle. This, however, is not always present. With a high power the ends of the beaded filaments are seen to run down the main stem in long, narrow, almost colorless cells. *B. monilifórm*, Fig. 82.

2. Anabæna (Fig. 83)

Filaments moniliform, freely floating; cells spherical, the larger scattered ones globular and yellowish. The filaments are often curved, and sometimes surrounded by a delicate

gelatinous material, in which the filaments are often collected together in a mass.

There are several species, all of which closely resemble one another (FIG. 83). They are supposed to be a stage in the development of some other Algæ.

Similar filaments, but with a gelatinous sheath, belong to the genus *Nóstoc.*

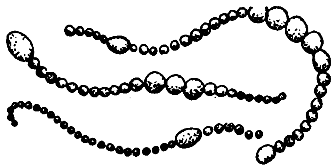


FIG. 83.—Anabæna.

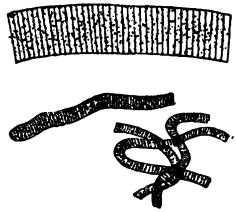


FIG. 84.—Oscilláría.

3. OSCILLÁRIA (FIG. 84)

These plants are found almost everywhere in standing water. They often form thick, floating mats of a dark purlish color or almost black, or they are found entangled among other plants in a dark green film.

Under the microscope they appear as filaments composed of many short cells, that vary a good deal in width according to the species, of which there are several.

They may usually be recognized by the bluish-green color, and by their characteristic motions. Some are like straight rods of cells bending slowly from side to side; others twist and writhe, and coil themselves into circles, only to uncoil slowly and repeat the movements. Some deliberately glide forward, the tip gradually and gracefully bending and curving. The movements, when the plants are in a healthy condition, are incessant. The observer need never be at a loss to recognize one of the several species of *Oscilláría.* Three forms are shown in the figure. (FIG. 84.)

Oscilláría is not in a sheath. A similar Alga is not uncommon whose filaments are singly enclosed within a colorless sheath, plainly visible at the extremities of the plant,

where it projects as an empty, membranous tube. This is *Lyngbýa*, and may be readily mistaken for a quiescent *Oscillária* unless the sheath is determined to be present or not. *Lyngbýa* is always motionless.

Oscillária frequently becomes so profusely developed in the microscopical aquarium, that it surrounds and drapes the large plants in a thin, mist-like cloud, and grows in wide patches on the sides of the glass. The color varies from the palest green to almost black, according to the species. There are thirty species, some of them growing on hot water.

Such a layer, composed of *Oscillária nigra*, perhaps an inch and a half square, traveled in twenty-four hours for five inches on the side of the microscopical aquarium, and then rolled itself into a cylindrical bundle at the bottom of the vessel.

4. Spirogyra (Figs. 85, 86)

The *Spirogýræ* are easily recognizable by the beautiful spiral bands of green within each cell, as shown very imperfectly in Fig. 85. There may be one, two, or more, sometimes as many as ten of these spiral, chlorophyl-bands winding on the inner side of the cell-wall. The number helps to determine the species, of which there are many.

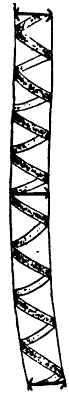


Fig. 85.—Spirogyra.

The plants usually grow in masses, and especially form those soft green clouds apparently floating just under the surface of the water. They are often entangled among submerged objects, but are almost as often free.

A feature common to several species of *Spirogýra* is minute, and for that reason easily overlooked, and perhaps on that account, all the more interesting. It is that in some species the two ends of each cell are folded in, an appearance said to be caused by the rapid growth of the plant. This is probably correct, as when the cells are forcibly separated, the folds disappear, and the ends project as smooth, more or less convex surfaces. In those species in which this

feature does not exist, the ends of each cell are straight, and extend apparently in straight lines across the filament. This structural point is worth observing, chiefly, perhaps, because it is so easily overlooked, and somewhat difficult to discover. The feature is shown imperfectly in FIG. 86.

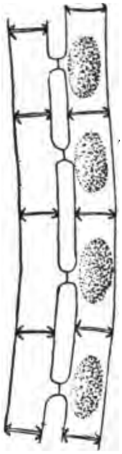


FIG. 86.—Spirogyra in conjugation; with spores.

It is sometimes necessary, it is always interesting, to ascertain the number of chlorophyl-bands in the cell. But this is not always an easy task. A simple method is to select, under a low power objective, a band near the middle of the cell, count the number of bands that cross it, and add one to the number, the additional one being the band chosen as the starting point.

Notice the nucleus in each cell. It appears to be a colorless little mass of protoplasm suspended in the middle of the cell, and connected with the cell-walls by several delicate radiating threads of protoplasm. The nucleus itself is within and surrounded by this little lump of protoplasm, and will probably escape observation unless it is specially looked for. It is a faintly pinkish little body, circular, and apparently flat like a minute disc. It is small. I have not measured it in any specimen, but I should estimate its diameter to be about five microns, or $\frac{1}{5000}$ inch. It is plainly visible after it has once been found, especially in those species in which the green chlorophyl-bands are few in number, and the spirals wide apart.

The nucleus is an important organ within the animal or the vegetable cell. It is not always present, nor always visible without the use of acetic acid, or of some other re-agent that will kill the animal, and so change the nucleus as to make it plainly visible. It may be apparent at one time in the life of the cell, and absent at another time. When present, and visible, it is usually readily recognizable, as its optical character is different from that of the surrounding body-sub-

stance (the protoplasm). Its aspect conveys the impression of solidity.

There may be only one nucleus in the cell, or a hundred or more. It is always small. In form it is generally a spherical or a flattened oval object; sometimes it is a long, narrow band; sometimes like a string of beads, in which the beads may be close together, or separated by the cord on which they appear to be threaded; sometimes like a bunch of grapes; sometimes a slender filament, curved and coiled like a worm. Its form may be almost as varied as the form of the plant or the animal of which it is so important a part. It is intimately connected with the life, and with all the vital activities of the cell.

The manner in which *Spirogyra* produces its spores is remarkable, but not confined to it, as some other Algæ have a similar method.

Each of the cells of two filaments lying side by side begins, usually at the same time, to protrude a narrow tube from those sides nearest each other. These tubes meet and grow together, so that the two plants soon resemble a ladder, the original filaments forming the sides, the tubes forming the rounds. The coloring matter falls away from the cell-walls; the entire contents of the cells of one filament pass through the rungs of this living ladder into the opposite cells, where the contents of both mingle. From this commingling the spore is formed, one in each cell, or one in each connective, or rung, of the ladder, and is, when ripe, ovoid and usually dark brown. This conjugation, as it is called, and the resulting spores are shown, in one species, by FIG. 86. The plants are often found in this condition in June and July, sometimes even earlier than June.

5. ZYGNÉMA (FIG. 87)

This usually floats unattached. The cells are rather wide and short. The internal stellate masses, by which it may always be recognized, are dark green in color. The formation of the spores resem-

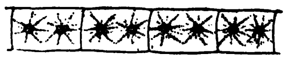


FIG. 87.—Zygnéma insígne.

bles that of *Spirogyra.* It is found in conjugation in April. *Z. insígne,* FIG. 87.

6. VAUCHÉRIA (FIG. 88)

A damp, green mat growing on the mud or in shallow water, not rarely exposed to the air, and resembling felt to both touch and sight, will usually prove to be *Vauchéria.* The filaments are long, with a few widely separated branches. The green matter is diffused over the cell-wall, and when the latter is broken flows out, and often forms green globules and irregular masses.

The spores are produced in two ways, both of which the microscopist will see, as they are not rare early in the year. In one method the end of a filament enlarges, becomes club-shaped, and a partition grows across it near the handle of the club. The contents of this new cell become dark, opaque, and hardened. The free end of the cell now breaks, and the spore slowly passes out, being squeezed into an hour-glass shape as it issues. It is covered by rapidly vibrating cilia, and no sooner is it free than it is off like a flash. But it soon settles down, and finally develops into a filament like the parent.

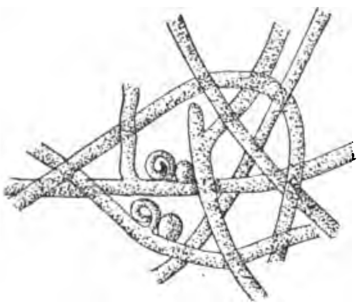


FIG. 88.—Vauchéria.

In the other method the filament produces from the side, as shown in Fig. 88, a small ovoid cell, and near it a narrow, curved or coiled tube. Presently the free ends of each of these cells open, and the contents of the tube pass into the ovoid cell, in which a spore without cilia is finally formed. This spore is said to fall in the mud, and to remain unchanged for many months, sometimes all winter, but finally developing into a *Vauchéria* like the one from which it sprung.

In some of the species the ovoid cells are grouped in a

cluster of several, and the whole, with the coiled tube, is raised above the filament on the end of a short stem.

7. Chætóphora (Fig. 89)

The light-green, jelly-like masses in which this Alga grows are found attached to submerged leaves of grass, to twigs, or to other small objects of the kind. They are often almost spherical, and vary in size from that of a pin-head to that of a marble. The surface is smooth, and so slippery that to pick up one of these *Chætóphora* jellies with the fingers is next to impossible.

The plant within the jelly is formed of fine, branching

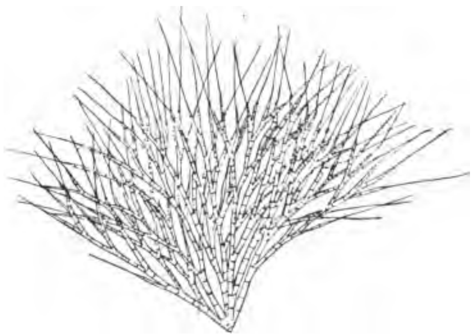


Fig. 89.—Chætóphora élegans.

filaments, usually radiating in all directions from a common center. The branches are shorter and most numerous near the surface of the gelatinous mass. Their ends bear a fine, colorless hair or bristle.

Under a low-power objective the plant, if carefully flattened out, is beautiful. It is justly named "elegant." *Ch. élegans*, Fig. 89. It is common. Only a small portion of the growth is shown in the figure.

Similar little gelatinous masses are, in my locality, sometimes inhabited by an *Œcistes*, one of the Rotifera (Chapter VIII), that instead of herself forming a jelly-like sheath for her home, as is the usual custom of the animal, inserts her

body within the algal jelly already formed, and there lives safe, and well-protected by the vegetable gelatine. A commendable, labor-saving device.

I once found another species of *Chætophora* attached to a floating chip, and so luxuriantly developed that it formed a thick, glistening green layer literally as big as my hand, and my hand is no microscopic object.

8. Draparnáldia (Fig. 90)

There need be no difficulty in recognizing this Alga. It grows attached to many submerged objects, the fine branches giving it a delicate, feathery appearance to the naked eye.

Under the microscope it is seen to be much branched, the branches arranged in clusters, each one formed of cells smaller than those of the main stem, and filled with chlorophyl, while each terminal cell is tipped by a long, colorless, hair.

The cells of the stem are but little longer than wide, but are usually colorless, except for a narrow, light green, chlorophyl-band that surrounds the middle. *D. glomeráta*, Fig. 90. It is common. Only a small part of a plant is shown in the figure.

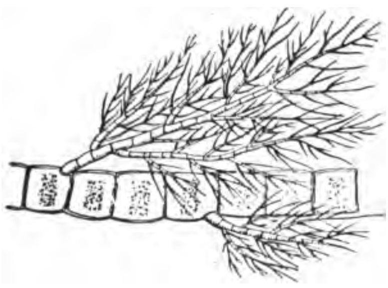


Fig. 90.—Draparnaldia glomerata.

Fig. 91.—Bulbochæte.

9. Bulbochæte (Fig. 91)

This genus can always be recognized by the swollen or bulbous bases of the long hairs that tip many of the cells.

It grows as a guest on larger Algæ, or on the leaflets of other aquatic plants (FIG. 91).

The Rev. Francis Wolle has completed his monographs on our fresh-water microscopic flora by the addition of his work on "The Fresh-water Algæ of the United States," to which the student is referred for technical descriptions of all the known American species, and for numerous illustrations.

CHAPTER IV

RHÍZOPODS

THE Rhízopods are the lowest animals in the scale of life. Scarcely more than a drop of jelly-like protoplasm, the lowest of these lowly creatures live, move, eat, and multiply. Some are so far down in the scale that they are actually only a particle of soft and unprotected protoplasm, moving, like the common *Amœba*, one of the Rhízopods, by protruding long, thread-like projections of its own substance from any part of its body, and withdrawing them again into its substance, where they entirely disappear. These protruded parts, by means of which the creatures move and capture their food, are called pseudopodia, from two Greek words, meaning false feet; and since they cften extend to long distances from the body of the animal, dividing and branching somewhat after the manner of roots, the group of lowly animals producing these pseudopodia is named the Rhízopods, or the root-footed.

The *Amœba*, and those Rhízopods nearest to it in structure, are formed of naked protoplasm; they are simply a drop of colorless, living jelly. Some that are higher in the same group secrete or build around their soft bodies a protective shell, often of exquisite form, always of remarkable construction. The members of one genus, *Difflûgia*, build for themselves shells of sand grains cemented together in perfect regularity, with every grain exactly fitted to its place. When the young *Difflûgia* happens to be where suitable sand is scarce, it will build its shell of Diatoms, often using those that are longer than the completed covering, attaching them lengthwise, side by side, and parallel to one another. Another genus, *Arcêlla*, secretes from its body a brown shell of delicate membrane, which with a high power is seen to be formed in minute

hexagons. Still another, *Clathrulína*, the most beautiful of all the fresh-water Rhízopods, lifts itself on a long stem, and there surrounds its body by a hollow, latticed sphere, and through the large and rounded openings in the walls, extends its pseudopodal rays in search of food.

In the unprotected forms the pseudopodia are protruded from any part of the body; in those furnished with a shell they are protruded from that portion of the body immediately in contact with the mouth of the shell, through which they often extend for a long distance as exceedingly fine, branching threads.

With a few exceptions the bodies of the Rhizopods are colorless. In those exceptions the coloration is usually due to the presence of colored food, and is either diffused throughout the entire protoplasm or confined to the parts near the surface, the central portion being nearly colorless. The pseudopodia are always without color.

Not only do the Rhizopods move by means of these "false feet," but with them they capture food, consuming both plants and animals. Diatoms, Desmids, Infusoria (Chapter V), Rotifera (Chapter VIII), almost any living thing, small enough to be seized, is acceptable.

When a desirable morsel is found, the end of the pseudopodium touching it usually expands, and a wave of the body-substance flows along it until the object is surrounded, like an island of food in a sea of protoplasm. The whole broadened pseudopodium is then withdrawn into the body, carrying the food with it; or if the captured object is unusually large, or if it struggle actively, several pseudopodia may come to the assistance of the first, or a great wave-like out-flow from the body may envelop both pseudopodia and food.

These peculiar animals have no distinct mouth and no distinct stomach. The mouth in the shell-less forms appears at any point on the surface, wherever the creature chooses to open itself and take in the food-particle; the stomach is in any and every part of the internal substance; the food is digested wherever it may happen to enter and remain.

They have no eyes, yet they seem to direct their course intelligently, and to avoid unpleasant or injurious obstacles.

They have no visible nerves, yet when disturbed they contract into a small, ball-like mass, or withdraw into the shell. They also appear to feel some sort of sensation of hunger, for they are often seen to take food, and they select what they like.

They are numerous and common. They are to be found in any shallow pond, or pool, or body of still water. They glide among aquatic plants and Algæ, especially on the lower surface of water-lily leaves, and among *Myriophýllum* and *Utriculária*. *Sphágnum* moss is sure to contain them in abundance, as has already been stated. But the mud at the bottom of any shallow, permanent pool is an accessible and always fruitful source of supply.

To obtain them, gently scrape with a big iron spoon, or with the edge of a tin dipper, the surface of the ooze on the mud in shallow ponds, and transfer it to the collecting-bottle. Let the muddy mixture stand for a few minutes until the Rhizopods settle toward the bottom. Carefully pour off some of the water, adding more ooze if desired.

Pour the mud and water into saucers; set these near the window, when the Rhizopods will make their way to the surface, and may be removed by the dipping-tube. Do not place the saucer in the sunlight; Rhizopods prefer a little shade.

They are invisible; consequently the collector must collect on faith, as he must usually do when out on a microscopical fishing-tour. But he will seldom be disappointed, if he gather the surface ooze from the edges of somewhat shady ponds, and if he avoid those places long exposed to the sun, and never sink the scraper into the thick black mud, which contains no animal life of any kind.

The rinsings from aquatic plants are a fruitful source of supply, not only of Rhizopods, but of all other classes of microscopic plants and animals. Gently shake the plants in an abundant quantity of water, allow the vessel to stand undis-

turbed for a short time so that the desired objects may settle toward the bottom, pour off the overlying water, and add more if desired. One or two repetitions of this rinsing will capture great numbers of microscopic creatures that can be caught only rarely, or with difficulty, by any other method. This rinsing added to the microscopical aquarium (Chapter V), will enrich it with many living creatures, and with eggs, or spores, or some other form of reproductive bodies that will develop there, and still further increase the student's microscopic flora and fauna.

Rhizopods are small. They are easily overlooked in the field of the microscope, but when one of the unprotected forms and a single shell-bearing Rhizopod are recognized the observer will never again overlook any of them in the material on his slide.

The *Amœba* will probably be the first seen as a colorless, jelly-like body, very soft and changeable in shape, slowly moving forward, suddenly altering its course, and extending itself in numerous long, blunt, finger-like pseudopodia, which are lengthened or shortened at the creature's will. Or he may see a small pear-shaped collection of sand-grains slowly moving across the field of view, apparently without a cause, although in such cases a careful examination of the narrow or stem end of the pear will show the long, fine, colorless pseudopodia issuing from that part, and he will know it to be a Rhizopod. After he has recognized a living shell he will have no trouble thereafter in knowing a dead one. By referring to the following Key he will be able to learn the name of any living form, unless it is a member of a very uncommon genus.

Key to Genera of Rhizopods

1. Body without a shell (*a*).
2. Body with a shell (*e*).
   - *a*. Without fine, hair-like rays; pseudopodia thick and blunt (*b*).
   - *a*. With fine, hair-like rays (in addition to pseudopodia) on all parts of the body (*c*).

b. Body colorless, very changeable in shape; often large. *Amœba*, 1.

c. Body orange in color or brick-red, with short pin-like rays. *Vampyrélla*, 2.

c. Body colorless or greenish (*d*).

d. Rays, not the pseudopodia, rigid, forked at the ends; body often green. *Acanthocýstis*, 3.

d. Rays flexible, not forked. *Actínophrys*, 4, or *Actinosphærium*, 5.

e. Shell a latticed globe on a long stem. *Clathrulína*, 12.

e. Shell formed apparently of sand-grains (*f*).

e. Shell not formed of sand-grains (*g*).

f. Not inclined; pear-shaped; or globular, with spines at the summit. *Difflúgia*, 6.

f. Inclined; circular or oblong; thicker and with spines at the rear. *Centropýxis*, 7.

g. Shell usually brown, sometimes colorless (*h*).

g. Shell colorless; ovoid, not curved (*i*).

g. Shell often yellowish; retort-shaped; neck curved; mouth downward, circular. *Cyphodéria*, 11.

h. Circular, depressed, with or without marginal teeth. *Arcélla*, 8.

i. Mouth oblique, circular, not serrated; shell inclined; without spines. *Trinéma*, 9.

i. Mouth serrated, not oblique; shell not inclined, formed of hexagonal or rounded apparently overlapping plates; often spinous. *Eúglypha*, 10.

1. Amœba (Fig. 92)

There is hardly a living animal so soft and changeable in shape as this. It may not retain the same form for a second at a time. The soft body protudes thick, blunt, finger-like pseudopodia from any part of its surface, but usually from the front margin, or that edge which, at the time, happens to be the forward part of the moving creature. The front may, with scarcely a warning, become the rear as the animal changes its course by emitting pseudopodia from some other

portion, and traveling off in the direction toward which they extend. The semi-fluid contents of the body are colorless, unless tinged by the food or by the presence of numerous dark-bordered particles, that are said to be crystals.

In a single instance I have seen an *Amœba* with these crystals formed of several, irregularly spherical granules, cemented together in the form of rod-like bodies with crenated margins, and measuring 11.25 microns (about $\frac{1}{2222}$ inch) in length.

Another specimen, taken from the microscopical aquarium, was abundantly supplied with crystals of the ordinary, dark-bordered, somewhat indeterminate form, and with numerous others in the form of straight rods, dumb-bells, and nails or clubs, that is, with rods that became gradually thicker toward the end, all having about the same length as those of the preceding *Amœba*. These were all freely mobile in the internal currents that followed the movements of the active body.

The movements are sometimes rapid, the *Amœba*, protruding its pseudopodia, keeping them extended in advance, and gliding along as though the body were formed of the white of egg.

In the figure, the animal is shown in what may be considered one of its favorite attitudes, as it resembles one frequently assumed. It is not possible to present a typical illustration of the soft and inconstant creature. When active it never has precisely the same form twice in succession, and seldom keeps its shape unchanged for two consecutive moments.

The posterior extremity, when the *Amœba* is in motion, may be entirely smooth, or it may show a cluster of very short pseudopodia, giving it a velvety or mulberry-like appearance. Suddenly a blunt, thick finger projects from the part, and *Amœba* at once reverses its course, and the pseudopodia at the front are withdrawn and disappear in the substance of the body. The observer can never predict what an *Amœba* will do next.

In the figure (FIG. 92) what appears to be an empty ring represents the body called the contractile vesicle, a clear

pinkish organ that slowly contracts and vanishes, only to reappear at the same spot, and to repeat its movements. It is supposed to receive the water unavoidably taken into the body of the animal with the food. It has also been proved to have a renal function. The organ expands as the fluid collects within it, and contracts to expel the water through an invisible channel into the surrounding medium.

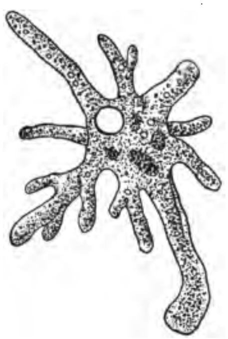


FIG. 92.—Amœba próteus.

The contractile vesicle is present in all Rhizopods, as well as in many other microscopic animals. At times it is somewhat difficult to find, but the pulsations, and its habit of entirely disappearing and then re-appearing in the same place, add much to the interest of its study. Some of these pulsating organs close slowly and deliberately, others so quickly that they seem to vanish with a snap, while still others contract with such violence that the animal's body is shaken by the shock.

In some microscopic animals there is only one contractile veiscle; in others there are two; in others there may be a score or more. In form they are usually spherical, but some are stellate; others a long, narrow, winding channel; others a narrow canal originating in a sphere.

Amœba is common in the ooze of shallow ponds and on the leaves of many aquatic plants. Its body generally contains a number of Diatoms, which form part of its favorite food. It is a strange fact that the food is usually taken by what, at the time, is the posterior extremity. There are several species. These often appear in large numbers in a microscopical aquarium that has been standing for a long time and contains much aquatic vegetation in not a really healthy condition. In such instances they appear especially abundant amid dead or dying Algæ. In their natural habitat in the open pond, they are never conspicuously abundant, and are rarely captured in great numbers.

The nucleus of *Amœba* is usually plainly visible as a broadly oval, or a sub-circular, flattened body, rather coarsely granular, and in length about 45 microns, or $\frac{1}{500}$ inch or less.

Prof. Joseph Leidy, in his monograph on the Rhizopods, says that it "usually occupies a position posterior to the middle of the body, but it may be shifted to almost any position, in the movements of the animal." In another place he tells us that it is "habitually posterior." Dr. W. H. Dallinger, in "The Microscope and its Revelations," after referring to nuclei that may retain their freedom to wander about, says in regard to *Amœba*, that the nucleus "is always distinctly visible," and is adherent to the inner portion of the ectosarc, the inner portion of the outer and less fluid surface of the *Amœba*.

Professor Huxley, writing of this part of the *Amœba*, says: "Physically the ectosarc might be compared to the wall of a soap-bubble, which, though fluid, has a certain viscosity, which not only enables its particles to hold together and form a continuous sheet, but permits a rod to be passed into or through the bubble without bursting it, the walls closing together, and recovering their continuity as soon as the rod is drawn away."

A question for the observer to decide is, Which statement is correct? If the nucleus may be shifted to almost to any position, as Dr. Leidy says it may be, it can hardly be adherent to the ectosarc, as Dr. Dallinger says it is, however firm that ectosarc may be.

It certainly appears to float freely in the semi-fluid substance of the animal, moving to and fro as it is influenced by the protoplasmic currents. I have several times seen it make a complete rotation on its short axis, and several incomplete rotations with a return to its former position. I have also witnessed, on one or two occasions, an incomplete rotation on the longitudinal axis. To see it carried forward nearly to the anterior border is not an uncommon sight. Such movements do not suggest attachment to the ectosarc, nor to any other surface. Leidy seems to have recognized its freedom of movement, since he refers to its passive shifting to any

part of the animal. But the reader may be able to solve the problem.

Species of Amœba

1. Body large, colorless, or enclosing many black-bordered, movable, crystalline bodies; pseudopodia finger-like, blunt. *Amœba próteus*, FIG. 92.
2. Body small, colorless, rather sluggish; often floating freely, and star-shaped, with several conical, acute, straight, or curved pseudopodia radiating from the spherical body. The form changes slowly. *A. radiósa.*
3. Body irregular in shape; pseudopodia usually few, short, thick, and directed forward; posterior portion of the body with a villous or velvet-like patch of very short, colorless projections. *A. villósa.*
4. Body irregularly round or oval, the broader front margin usually rather evenly curved; surface generally smooth, but nearly always marked by from one to four longitudinal lines or wrinkles, that are almost characteristic of the animal; pseudopods few, short and blunt. The animal advances by a steady forward flow of the body-substance; small, varying in length from $\frac{1}{625}$ to $\frac{1}{200}$ inch, or from 40 to 120 microns. It is common. *A. verrucósa.*

2. VAMPYRÉLLA LATERÍTIA (FIG. 93)

A red or orange-colored, Amœba-like creature with this name is not uncommonly found in early spring among thick growths of *Spirogýra*, for which it has a special fondness. It does not quickly nor frequently change its shape, yet its movements are somewhat rapid.

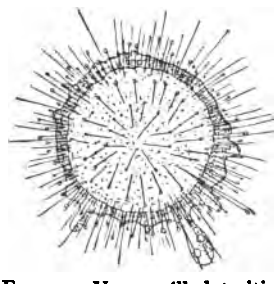


FIG. 93.—Vampyrélla lateritia.

Its pseudopodia are colorless and transparent, being formed by a short outward flow of the colorless, internal body-substance. Its red color is confined chiefly to the superficial regions.

It has in addition to the pseudopodia, short, fine rays like threads, and many pin-like projections, by which, in connection with its color, *Vampyrělla* may be easily recognized. These pin-like rays consist of a short, fine stem with a little bulbous enlargement on the end, so that each looks much like a pin with a big head. These may appear on all parts of the body, but usually they are on only the posterior end when the animal is moving. They often appear suddenly, and as quickly vanish. They are usually more frequently developed and more abundant on the young animal on which they may be produced and retracted with surprising quickness. As the animal becomes older, it seems to be more reluctant to project them; when it is ready to reproduce itself by entering on the encysted stage, to undergo reproductive division, a pin-head is seldom visible.

Vampyrělla is not rare. At times it may be captured in some abundance. In the latter part of March, I have gathered from the bottom of a shallow brook that trickled gently down a hill-side, a quantity of ooze that proved to be rich in Rhizopods, *Vampyrělla,* being so plentiful that I had six of them on a single slide.

Vampyrělla's favorite food appears to be the cell-contents of *Spirogyra.* It selects a fresh and healthy plant, and settling on it, proceeds to perforate the cell-wall, and to remove the color-bands with the entire cell-contents, by drawing the whole mass into its body, leaving the cell entirely empty and with a ragged opening in the side.

In the gathering just referred to, a *Vampyrělla* made its way rapidly across the field of view, and, as if some innate knowledge, surely as if a rational impulse were guiding it, without hesitation this little orange-colored mass of living jelly passed directly to a filament of *Spirogyra,* to which it attached itself. One minute later, I was surprised to see the first turn of the chlorophyl-band within the cell suddenly fall down. In another minute the second turn followed; in three minutes, the entire cell-contents were loose and slowly gliding toward the *Vampyrělla,* that was comfortably sucking

them in. In five minutes the cell was empty, and the hungry animal was moving to the next. Here the operation was repeated. In its third excursion, it placed itself across the partition wall between two cells, and proceeded to imbibe the contents of both at once. It was not until seven cells were emptied that its appetite was satisfied. I have since witnessed a repetition of this by another individual *Vampyrĕlla* with a smaller appetite.

In the gathering from the hill-side brook, *Vampyrella* was actively reproducing itself, by enclosing its body in a transparent covering secreted by itself, to form what is called a cyst, in which it was about to undergo division. On the filaments of *Spirogyra* such cysts were so plentiful that many filaments bore three or four, and occasionally two were attached to opposite sides of the same cell. In the field of a $\frac{1}{8}$ inch objective, I have seen eight of these cysts, from some of which I saw three young *Vampyrĕllæ* make their exit, two passing out simultaneously from opposite sides, the third following through one of the apertures already made. So active were they, so overflowing with vitality, that they attached themselves and formed their cysts on any thread-like object in the field, even on woolen fibers and bits of lint.

3. Acanthocystis chætóphora (Fig. 94)

Body spherical, soft, usually colored green by the numerous green granules within. When the animal changes its shape, which it seldom does, and then slowly, it becomes oval or slightly irregular in outline.

The pseudopodia are fine and hair-like. They spring from all parts of the surface. The peculiarity by which the animal may easily be recognized is the dense growth of spines covering the entire surface of the body. Their ends are forked, or divided into two short, straight, diverging branches. To see these forked ends clearly demands a rather high-power objective, as they are small, but the spines themselves are visible with a comparatively low-power. These seem to be insecurely fastened to the animal. Some of them often become

loosened and drop off, especially if the Rhizopod is not in a healthy or a comfortable condition.

These forked spines are attached to the surface of the body by minute discs, from which each spine appears to spring. These are exceedingly small, but so numerous that they appear to form a protective coating to the animal's body. They are seen with some difficulty, except when the spine has become detached from the body and is free in the field.

When food is to be taken, a part of the surface with the adherent spines is lifted up, carrying these ornaments to one

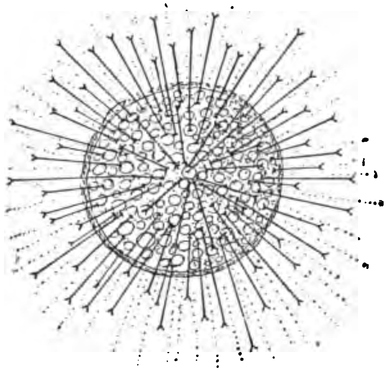


FIG. 94.—Acanthocystis chætóphora.

side, and a wave of protoplasm, the body substance, flows out to receive and to surround the food brought toward it by the pseudopodia. It is drawn into the body, the surface closes, and the spines again cover the spot. This may take place at any part of the surface.

Acanthocýstis is found among the leaflets of *Myriophyllum*, the roots of *Lemna*, or floating freely in quiet water. It is rarely found in the mud. It seems to be more fond of the sun than are most Rhizopods.

4. ACTÍNOPHRYS SOL (FIG. 95)

This is one of the commonest of aquatic microscopic animals. It may be found floating in almost any quiet pond

and pool, or among the leaflets of nearly every gathering of water-weeds. Its body is usually colorless and almost transparent, and appears to be formed of a collection of small bubbles, so that it has a foamy appearance, and it always bristles with numerous, long, fine rays that spring from all parts of the surface.

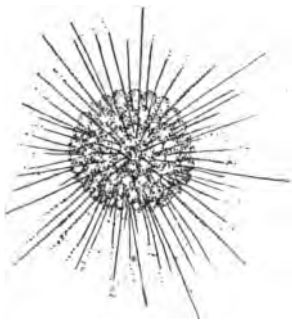


FIG. 95.—Actínophrys sol.

It moves in a slow, gliding way that has not been satisfactorily explained, but that can hardly be produced by the hair-like rays, for they are motionless, and apparently are used only for the capturing of food. The animal slowly floats across the field of view, seldom changing its shape, or it remains suspended almost stationary in the water with all its rays extended, and so resembling the pictures of the sun in the almanac, that it has received the name of the "sun animalcule." The rays are seldom entirely withdrawn.

It feeds on smaller animals and upon the spores of Algæ. When an animalcule comes in contact with the rays it seems to lose some of its power of motion. It appears to become partly paralyzed, and glides down the ray, often surrounded by a small drop of protoplasm until it nears the body, when a larger wave flows out and receives it. The little masses of digesting food may be seen inside the body, where the green color usually soon turns brown.

The contractile vesicle is here unusually vigorous in its movements. Although it may be on the side of the animal that is directed away from the objective, yet at every contraction, the movement makes itself known by the tremor that it communicates to the entire body, so that, although it is not visible, the observer may count the number of its pulsations, by counting the shocks that accompany its collapse.

In this Rhizopod, the contractile vesicle does not discharge its contents into the surrounding water. As the organ contracts, its anterior surface is extended in numerous, short, finger-like projections that finally retire, as the whole vesicle sinks to a level with the general surface, or even somewhat below that level.

There is only one other contractile vesicle of which the writer knows among microscopic animals, that acts in a similar way, that of *Actinosphærium.* But the reader can hardly hope to see this interesting structure, as the parts are exceedingly small, demanding a high-power objective, at least a $\frac{1}{8}$, and an eye that has been well trained in microscopic observation, and has learned to detect exceedingly minute objects. To such an eye, the villous surface of the contractile vacuole is readily apparent in both *Actinophrys* and *Actinosphærium,* provided the Rhizopod is in a favorable position.

The nucleus of *Actinophrys,* not shown in the figure, is usually seen with ease, especially if the Rhizopod have been deprived of food for a short time. It appears as a light spot in the center of the body, with a circular, sharply-defined border. It seemingly is a flat disc. It is visible under a low-power ($\frac{1}{2}$ inch or $\frac{4}{10}$ inch) objective, and then seems to be a pale body without any special structure; but with the $\frac{1}{8}$ inch or a higher-power objective, it is seen to be finely granular, particularly on the surface. It is about 19 microns ($\frac{1}{1300}$ inch) in diameter. It could not be more truly circular, nor more truly central.

5. Actinosphærium Eichhórnii (Fig. 96)

At first the reader will confound this Rhizopod with *Actinophrys sol,* which it resembles in appearance when seen with a low-power objective. It is larger than the "sun animalcule," but this distinction is valueless unless the observer has happened to find *Actinophrys* first, and to have become familiar with its appearance and structure. In *Actinosphærium,* the ray-like pseudopodia are remarkably large and coarse, and taper to their free end from a thickened base at the surface of the body.

The body itself, as the student will notice if he uses a $\frac{1}{4}$ inch or a $\frac{1}{8}$ inch objective, is formed of an external layer of large vesicles or bubbles, and a central mass of smaller protoplasmic vesicles. In this bubble-like structure it also resembles *Actinophrys*, but it appears less like a drop of froth, for the vesicles are larger, and the two distinct layers of two different sizes at once show that the Rhizopod is not *Actinophrys*, but is *Actinosphærium*.

There is still another and more important difference, that the reader may not observe unless he search for it with a high-power ($\frac{1}{4}$ or $\frac{1}{8}$) objective, and even then the structure is not easily observed when first it is looked for; but each ray has a thread, or fine, rod-like filament running lengthwise through its middle, and differing slightly in color from the softer part of the ray. This rod originates within the body, below the outer layer of large protoplasmic bubbles, passes out between them, and extends almost to the end of the pseudopodal rays, which are seldom withdrawn into the body.

Actinosphærium is sluggish. It moves slowly and often remains motionless for a long time in one spot. It is frequently found in company with *Actinophrys*, among *Lemna* and other aquatic plants. It too, seems to like the sun.

It feeds on other animals as well as on plants, taking larger victims than the "sun animalcule" will select. The Rotifera (Chapter VIII) seem to be its favorite food. A free-swimming animalcule or a Rotifer coming in contact with the long rays, often seems, as with *Actinophrys*, to become incapable of escape; it is then slowly drawn into the body and digested. I have seen an *Actinosphærium*, the body, without the rays, $\frac{1}{100}$ inch in diameter, that had swallowed an *Arcella* $\frac{1}{300}$ inch in diameter. Like the majority of microscopic animals, *Actinbsphærium* always has a good appetite.

The circle on the lower, right-hand edge of the figure (FIG. 96), represents the contractile vesicle. In this Rhizopod it is large and usually conspicuous. After its pulsation, it always reappears in the same place. *Actinosphærium* has two of these organs. Only one is shown in the figure.

At the moment of its contraction, the contractile vesicle acts in a way similar to that of *Actinophrys sol*, although its movements take place at longer intervals, and are not accompanied by the shock to the animal so characteristic of that special Rhizopod. But the surface of the vesicle is extended in numerous, finger-like processes, unequal in size and in length, and so much larger than those of *Actinophrys sol* that they may, by a practiced eye, be seen with a $\frac{4}{10}$ inch objective, if the *Actinosphærium* be in a favorable position.

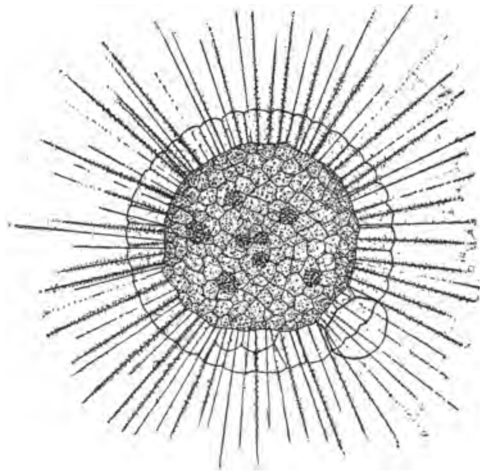


FIG. 96.—Actinosphærium Eichhörnii.

When the vesicle (or vacuole) has reached its point of greatest expansion, its surface is entirely smooth, but as it contracts, that surface becomes studded with the hollow projections. These are forced out from the general surface of the vesicle with violence, their free extremities becoming suddenly rounded by the pressure from within. The entire performance reminds the observer of the childish sport of blowing into a kid glove to see the inflated fingers leap out. The projections are either slowly withdrawn and so made to disappear, or they are smoothed out by the gradual expansion of the swelling vesicle.

Actinosphærium, unlike *Actinophrys*, has several, sometimes more than a hundred, small nuclei scattered just below the layer of large vesicles, or bubbles, that form the outer portion of the body. The nuclei are seldom easily seen; usually they are entirely invisible, until a few drops of dilute acetic acid have been allowed to run under the cover-glass and to come in contact with the Rhizopod. The acid acts on the nuclei in such a way that, to a practiced eye, they become visible under a low-power objective. It is a satisfaction to the microscopist to know that they are present. Actually to see them is a pleasing experience, that I have had in only a few instances with the living Rhizopod. They were there so numerous that the body of each was speckled with them, and so conspicuous that in one I counted one hundred and eighty-eight; in another, one hundred and ninety-three; and in another, two hundred and fifty-eight. Twice these numbers were probably present in each. The animals themselves were large, measuring about 1070 microns ($\frac{1}{23}$ inch) in diameter, and unusually vigorous. The nuclei were apparently circular discs, but were really spheres, irregularly scattered, and about 20 microns ($\frac{1}{1250}$ inch) in diameter. Each *Actinosphæriun* was visible to the naked eye as a whitish dot, adherent to the side of the microscopical aquarium.

In these instances, the nuclei were visible with the one-inch objective, and the animals were speckled with them like the road-paver's concrete with pebbles. Among many large and vigorous specimens collected at the same time, from the same pond, some exhibited their nuclei, while others on the same slide were, to all appearance, without a single one. Why two specimens side by side should each present a different structural aspect is one of nature's mysteries. The reader may be able to solve the problem.

Although the external layer of large vesicles, or protoplasmic bubbles, is characteristic of *Actinosphærium*, and plainly tells the observer that it is not *Actinophrys*, yet the inexperienced microscopist may be in doubt. The presence of a central, circular, lighter-colored, nuclear spot, will at

once dispel that doubt, as such a central body is never visible in *Actinosphærium*, but is always present in *Actinophrys*, although the microscopist may be compelled to search for it by a change of focus, and by careful scrutiny. But aside from this minute, structural difference, the coarser pseudopodal rays with their central, rod-like body, the two vesicular layers that comprise the animal, will tell the story of its identity.

6. Difflúgia (Figs. 97, 98)

Shell brown, pear-shaped, ovoid or nearly spherical, formed of angular sand-grains firmly cemented together. The upper part, the summit or fundus, may be rounded, and roughened only by the projecting edges of the sand-grains, or rounded and bearing several pointed spines likewise formed of sand. The lower region may be prolonged as a short neck, at the end of which is the rounded mouth for the passage of the pseudopodia; or the shell may be without a region resembling a neck.

The animal that builds this protective case lives within it, and is a little mass of colorless, or sometimes greenish, protoplasm, somewhat closely resembling an *Amœba*, and usually almost entirely filling the cavity of the shell. The mouth of this domicile of sand is circular, and may either be smooth or have several rounded teeth or lobes on its inner edge.

No part of the healthy and comfortable animal, except the pseudopodia, in any of the shell-bearing forms, ever passes through this mouth. After the shell is made, the animal usually leaves it only when it has been broken by the cover-glass or otherwise injured, when the protoplasmic body will at times creep out and die.

The writer has observed across the mouth of the shell of *Difflúgia urceoláta* what he at first thought to be an *Amœba próteus*, which appeared to be passing by. A higher-power objective showed that the *Amœba* was not wandering by the home of a relative, but was coming out of its own front door, and was in visible connection with the concealed portions of the owner and inmate. The shell was

sufficiently transparent to show the passage to and fro of the protoplasm and of its granules, between the exterior *Amœba* and the partly concealed internal sarcode, and to prove that the former was but an extension of the *Difflugia* itself. The Rhizopod appeared about to change its residence, or to undergo an alteration still more momentous. The movements of the extruded mass were amœboid and active, and its resemblance to *Amœba prôteus* was close, with the exception of its habit of protruding numerous, short projections which gave it a villous appearance, resembling that of *Amœba villosa.*

Twenty minutes after it was first seen, the protoplasmic current suddenly flowed toward one direction, and poured out of the shell, dragging the posterior extremity thickly villous. It was then to all appearance a large and active *Amœba villosa,* and would certainly have been so considered had not its exit from the shell of the *Difflugia* been witnessed. It extruded no pseudopodia, but moved forward by a steady onward flow of its protoplasm. The villous patch was always visible, and an interesting fact is, that the observer, by carefully watching this velvety region, could predict a change in the direction of the *Amœba's* movements. When the patch appeared on the advanced extremity, the *Amœba* at once began to move in the opposite direction. It seemed as if the creature considered the velvety spot as a cluster of enemies to be avoided.

After becoming densely villous over the entire body, it rested for a few minutes, when it resumed its motions and wandered about the field of the microscope, becoming quiescent at intervals, until the observer was compelled to leave it. On his return it was dead. Its exit from the shell was probably caused by some discomfort, or by some other cause impossible for a human being to discover.

Although discomfort is the usual cause of such conduct, Dr. G. C. Wallich reports that he has seen the common *Amœba* explore the mouth of an old and abandoned shell of *Difflugia,* much, I suppose, as the hermit-crab will examine an apparently acceptable sea-shell before leaping into it. Dr. Wallich also states that the *Amœba* finally approved of the domicile as a

home, and entering took possession, thenceforth protruding its pseudopodia, and dragging the shell about, as if it had been originally formed by its new occupant.

The pseudopodia are blunt and colorless. They move the shell with the mouth directly downward, and capture food as in the naked Rhizopods.

When they are withdrawn, the shell appears like a dead thing, and may be rolled about the slide at the will of the observer, or the mercy of the currents. But often, while the student is looking at an apparently dead shell of sand, a blunt little wave of colorless protoplasm issues from the mouth, lengthens and narrows, is followed by another and another, until the shell is raised and moved slowly away, one of the most remarkable of microscopic creatures.

There are several species of the genus *Difflúgia*, of which the following are among the commonest. They are found abundantly on the mud, and also among the leaves of *Sphagnum*, and of other aquatic plants.

Species of Difflúgia

1. Shell pear-shaped (FIG. 97); without spines, although the summit may be prolonged into one or two points; usually formed of sand-grains, sometimes with adherent Diatoms; occasionally formed entirely of Diatoms; mouth at the narrow end, circular, smooth, without teeth or lobes.

   The body within the shell is usually green, sometimes colorless; pseudopodia colorless, thick, blunt.

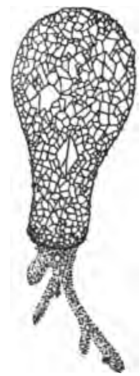


FIG. 97.—Difflúgia pyrifórmis.

The animal is almost as fond of the cell-contents of *Spirogyra* as is *Vampyrella*, and obtains them in a similar way; but instead of appearing to suck them out of the cell, *Difflúgia pyrifórmis* pierces the wall, inserts its pseudopodia, with them surrounds the color-bands and other cell-contents, lifts the entire mass out

and passes it into the body within the shell. I have seen a single *Difflúgia* empty four *Spirogýra* cells in succession, and, on another occasion, I have had in the field, a long, colorless, algal filament, entirely empty, resembling a colorless glass tube, and perforated at somewhat regular intervals, by holes with ragged margins, the work of a hungry *Difflugia.* This species, *Difflúgia pyrifórmis*, FIG. 97, is common.

2. Shell nearly spherical; with from one to twelve, usually from three to seven, pointed spines arranged in a circle around the upper part, and formed of sand-grains. These spines are hollow, and communicate with the cavity of the shell, but the animal probably builds them for ornament, as it never seems to use them.

The mouth of the shell occupies the end opposite to the spine-bearing summit. When the shell is turned over, so that this opening is directed upward, it will be seen to be lobed or scalloped, the lobes varying from six to sixteen, being usually about twelve. They may, in some forms, be rather sharp-pointed, almost like short teeth, and are in all cases directed toward one another across the opening.

It is a difficult matter to get the shell in such a position that the observer can look down into its mouth, but this may sometimes be done by tapping the cover-glass with a needle so as to roll the Rhizopod about; occasionally, by one of those lucky accidents that sometimes occur, it will place itself in good position for the purpose.

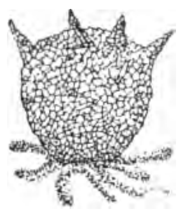


FIG. 98.—Difflúgia coróna.

The soft body is colorless or brownish. The pseudopodia are thick, blunt, and numerous. The species is common in the ooze. *D. coróna*, FIG. 98.

3. Shell spherical; without spines; lower surface flattened; mouth circular, smooth, without lobes or teeth. This species is found with the preceding. *D. globulósa.*

4. Shell long and narrowly pear-shaped, the summit prolonged into a central, conical projection or sharp point; mouth

circular, smooth, without teeth or lobes. Common. *D. acumináta.*

7. Centropýxis aculeáta (Fig. 99)

The shell of this Rhizopod is usually formed of sand-grains, and is brown in color. Sometimes it consists of a brown membrane with only scattered sand-grains adherent. The author has also met with shells formed entirely of small Diatoms, fitted together as beautifully and as accurately as are the sand-grains of *Difflugia*. These diatomaceous dwellings were found in an aquarium, and were probably built of these plants because suitable sand was not to be had.

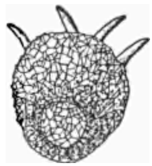


Fig. 99.—Centropyxis aculeáta.

Centropýxis, when seen in side view, appears as if it had once been a hemisphere with the mouth near one edge of the flat surface, but that while it was soft the convex part had, in some way, been pushed over toward one side, thus leaving the shell oblique or inclined. The back part is much thicker than the front, the upper surface sloping down from the higher rear to the shallower anterior margin, the circular or oval mouth remaining nearer the thin border.

The figure shows the lower aspect of a shell, which in this position, appears almost circular. The spines on the thick parts are usually sharp-pointed, and vary in number from one to nine.

The body of the animal is colorless. The pseudopodia are blunt and finger-like. This is the only known species. It is common. *Centropýxis aculeáta.*

8. Arcélla (Figs. 100, 101)

When seen from above or from below, the shell of *Arcélla* appears like a disc with a pale circular spot in the center. When seen in side view it has a flat, inferior surface, and a more or less strongly convex or elevated upper surface. In color it is usually some shade of brown, but may be yellow or

almost black. In young specimens the shell is often nearly colorless. It is generally transparent. The mouth of the shell, in the center of the flat lower surface, is circular and smooth.

The contractile vesicles are numerous. In the lighter colored specimens they are distinctly visible, arranged at irregular intervals around the margin of the body. In one of these pale, apparently young *Arcéllæ*, I have seen ten

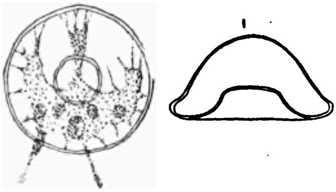


FIG. 100.—Arcélla vulgáris.

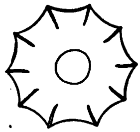


FIG. 101.—Arcélla dentáta.

Under favorable conditions, these Rhizopods may rapidly increase in numbers. On the same slide, made with a drop of water, and a few small fragments of an aquatic plant, from a supplementary, watchglass aquarium that had been standing on my table for several days, I have had, by actual count, one hundred and ten *Arcellæ*, varying from a perfect, almost colorless tansparency, to a deep chestnut-brown, all of them gliding about the cell, pseudopodia extended and motile, contractile vesicles pulsating, every one of the little animals bubbling over with vitality. I flooded them from the slide back into the aquarium. If I had wiped them away, and so destroyed them, I should have felt like a murderer.

The shell itself, under the $\frac{1}{8}$ inch objective, appears to be composed of minute hexagonal elements, so minute that they measure only $\frac{1}{12000}$ inch or about 2 microns in width, yet the $\frac{1}{8}$ inch objective will reveal them distinctly, provided the student's eye is well trained and his vision acute. They are so pleasing in their regularity and their neatness, that they give the shell not only a beautiful but an artistic aspect. But this apparent structure is only superficial. The true structure

of the shell is complex, and can be made out only by careful scrutiny under a first-class objective of high power, and even then is not an easy task.

The body is colorless, and is attached to its home by fine, radiating threads of its own substance. There are several species, to be recognized by the form of the shell.

Species of Arcella

1. Margin of the shell smoothly circular. Common everywhere. *Arcélla vulgáris*, FIG. 100, *A* being a side view of an empty shell to show its flattened dome-like form, and the manner in which the margin of the orifice is turned in to produce an internal mouth to the shell. This is one of the characteristics of all *Arcellæ*.
2. Margin of the shell with several teeth, so that it resembles, when seen from above or from below, a wheel with pointed shallow cogs. Not so common as the preceding. *A. dentáta*, FIG. 101.
3. Shell somewhat balloon-shaped when seen in side view; higher than wide, the sides often depressed in wide facets. Not rare. *A. mitráta*.

9. TRINÉMA ÉNCHELYS (FIG. 102)

This shell is pouch-shaped, colorless, small, and inclined, so that when in motion with the mouth downward against the slide, the rounded summit is lifted obliquely upward. It is somewhat narrower at the lower part, and the mouth is a short distance within the shell, the front or lower edges appearing to curve inward to meet it or to form it.

FIG. 102.—Trinéma énchelys.

The body of the animal is colorless.

The pseudopodia are fine, thread-like and few in number, three being the usual number visible at one time. It is on account of this peculiarity that the genus has received the name of *Trinéma*, or "three threads."

The Rhizopod is common everywhere in wet places, and

is one of the smallest members of the group, measuring from 16 to 100 microns in length. The shell is often found dead and empty. The figure shows it in side view.

The aperture of the shell is seen to be beaded, when examined with a high-power objective.

10. EÚGLYPHA (FIG. 103)

The shell of *Eúglypha* is ovoid, colorless, and transparent. Under a high power it is seen to be composed of many oval or hexagonal plates arranged in rows, those toward the widest part of the shell overlapping those in front. The mouth is circular or oval, the projecting points of the plates giving it a toothed, saw-like edge.

There are several species, but they all may be known as *Eúglyphæ* by this serrated or saw-toothed mouth.

The free margins of the saw-like teeth that form the border to the mouth of the shell, are themselves delicately and finely toothed, or serrated. This, under the $\frac{1}{8}$ or higher-power objective, is a beautiful structure, and worth seeing clearly and sharply defined.

The upper part (the fundus) and the lateral margins of the shell, are either with or without spines, or the spines may be represented by long, slender, hair-like bristles. In some specimens the spines are short and robust, like those in FIG. 103; in others they may be more slender, longer and arranged at some distance below the rounded fundus of the shell, while in still others they may be represented by the hair-like bristles. The last-mentioned form is the prevailing one in the writer's locality. I have had seven on the slide at one time, five of them in the field. In the *Sphagnum* of this region, *Euglypha ciliata* is the common and plentiful species.

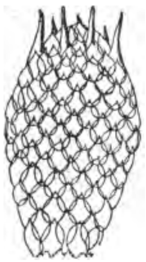


FIG. 103.—Eúglypha alveoláta.

There are two contractile vesicles, opposite each other, one on each side of the body, near the middle of the side.

These are seen by the $\frac{1}{8}$ inch objective with little difficulty, provided they are not obscured by food, as they often are.

The animal itself is colorless, and usually does not entirely fill the cavity of the shell, to which it is attached apparently by the summit only.

The pseudopodia are delicate and often branched. The animal moves, like all the shell-bearing forms, with the mouth of the case against the slide or other object over which it glides.

Species of Euglypha

1. Shell without spines, or with four or six near the summit, and arranged in a circle at equal distances apart, pointing upward and varying somewhat in length. Rather common in the ooze of ponds. *Eúglypha alveoláta*, FIG. 103.
2. Shell with a cluster of spreading or diverging spines springing from the center of the summit. Common among *Sphagnum*. *E. cristáta*.
3. Shell with the summit and sides fringed with bristles. Common among *Sphagnum*. *E. ciliáta*.

11. CYPHODÉRIA AMPÚLLA (FIG. 104)

Shell yellowish, or sometimes colorless; shaped like a chemist's retort, the mouth being at the narrow, curved neck-like end. The summit is rounded, sometimes having a central point or small knob. The shell, when highly magnified, is seen to be formed of minute hexagons.

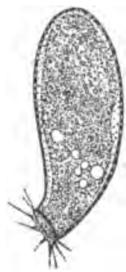


FIG. 104.—Cyphodéria ampúlla.

The animal is, as usual, colorless, and nearly fills the semi-transparent case. The pseudopodia are numerous and often forked.

When the animal is moving, the mouth of the shell is in contact with the object over which the Rhizopod is traveling, and the body of the shell is held obliquely upward, or at times almost parallel with the slide. There is but one species, which is rather frequent in the ooze of ditches and ponds. Length from 112 to 176 microns.

12. CLATHRULÍNA ÉLEGANS (FIG. 105)

A hollow globe of silicious lattice-work elevated on a crystalline stem. Within this exquisite dwelling the spherical, colorless animal lives, extending its fine, long pseudopodal rays through the almost circular windows in search of food. The stem is attached to aquatic plants or to other submerged objects. *Clathrulína* is therefore the only fresh-water Rhizopod that is not free-swimming. It is common in many ponds, attached to Algæ or to the rootlets of *Lemna*. It can never be mistaken for anything but what it is, even at first sight.

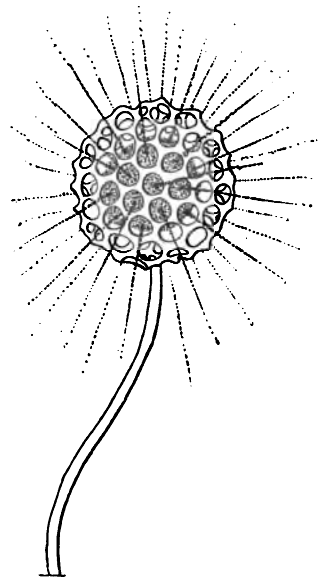


FIG. 105.—Clathrulína élegans.

When young, this perforated, delicately beautiful sphere is colorless; with advancing age, it may become yellow, or even chestnut-brown.

Not rarely, what may be called a *Clathrulína* colony appears in the field of view. In such a beautiful collection, a young form has attached its stem to the latticed capsúle of the founder of the group, a still younger one has erected its capsúle on the second as a support, until the collection may number four or five, or more, all actively alive, all protruding their pseudopodia through the openings in the globes, but each entirely independent of the others, and leading a separate existence. To find such a colony is a pleasing experience in the microscopist's life. To find two *Clathrulinæ* thus united is not an unusual occurrence. In a single instance I have seen a cluster or colony of the kind formed of ten of these beautiful creatures.

Little is known about the methods of reproduction among

the Rhizopods. *Amœba* and certain other unprotected forms multiply by transverse fission. The soft body divides into two parts, each part becoming an independent animal. This method has been observed with *Clathrulina*, in which the imprisoned body separates into two or more similar portions, one or more of which pass out of the sphere through the perforations, and finally develop into the form of the parent.

The method more frequently observed, and that explains the formation of the colonies, takes place in the early spring, often as early as the first of March.

A part of the body separates in a small mass that assumes a long ovate form, develops two flagella at the pointed front end, emerges from the sphere as a free-swimming zooid and for a short time, leads an independent, roving life. It then resembles an Infusorium. It soon evinces a desire to settle down, as it does permanently wherever it may happen to find a favorable spot, not rarely selecting the surface of the latticed globe from which it came, and there developing a stem and a sphere of its own.

Little is known of the manner in which the Rhizopods form the beautiful shells that they occupy. Those like the domiciles of *Arcella* and the perforated globe of *Clathrulina*, are secreted from the body of the animal, but just how they are moulded or shaped is not known. Those Rhizopods that, like *Difflugia*, build shells of sand grains are supposed to swallow the building materials as they swallow their food, and to pass them to the surface of the body, there fitting together the sand-grains into the graceful forms with which we are familiar, but further than this little is known.

In this small book, it is possible to refer to only a few of the commonest of these beautiful and interesting animals, about whose life history we know so little. They form a department in which there is room for much original investigation.

Those that desire to pursue the subject, or to know more of the Rhizopods than can be included here, would do well to refer to Dr. Joseph Leidy's "Fresh-water Rhizopods of

North America," published by the United States Geological Survey of the Territories, F. V. Hayden, Geologist in Charge; or to Mr. Romyn Hitchcock's "Synopsis of the Fresh-water Rhizopods," a useful condensation of Dr. Leidy's splendid work.

CHAPTER V

INFUSÓRIA

THE reader probably knows the Infusória under the name of animalcules, a word meaning small animals, which the Infusoria certainly are. But a mouse is a small animal; so is a Water-flea (Chapter X) and a Rotifer (Chapter VIII). Infusórium for a single one of a group of certain microscopic creatures, and Infusória as the plural, are better words than animalcule, with no danger of conveying an incorrect meaning.

The Infusoria were so named because they were first discovered in infusions, that is, water in which animal or vegetable substances had been soaking and decaying. Since that time the creatures have been obtained in great abundance and variety in even the sweetest of fresh water, although they abound in astonishing numbers in many infusions. The reader has only to place a handful of hay in a tumbler of water, and allow it to soak for a week or two, or even for only a few days, when he will have as many Infusoria as he may want for examination. They are also plentiful in every ditch and pool of still water. No collection of Algæ, aquatic plants, or Rhizopods can be made without, at the same time, gathering many Infusoria.

One of the best ways in which to collect the little creatures is to gather aquatic plants and Algæ without entirely removing them from the water. If the plants among which the Infusoria conceal themselves and search for food are lifted out of the pond, the water running off washes away many of the animals that the collector is seeking.

The Infusoria are fond of fresh air; they rapidly exhaust the oxygen in solution in the water, dying quickly, and going to pieces almost as soon as dead. Give them plenty of air in the collecting-bottle, and at home pour the gathering into

a broad vessel, so as to have a wide surface exposed to the atmosphere, the plants as well as the Infusoria doing better in such quarters. They are also usually fond of the light, and will soon make their way to the side of the vessel nearest the window, and the dipping-tube put in at that side will often capture creatures that avoid the shadier parts.

To obtain those that are free-swimming, that is, those which are never permanently adherent to the leaflets of plants nor to the filaments of Algæ, as many of the most interesting are, they may be transferred to the slide by the dipping-tube, and the drop covered by the thin glass, when they will be ready for study.

Those attached to plants can be found only by cutting off a small piece of *Myriophyllum* or of other water-weed, and examining it under the microscope. Some of the most interesting kinds of Infusoria are found adherent to *Utricularia* and to other plants with finely divided leaves. Every part should be searched with the microscope, especially the angles between the leaflets.

The bodies of the Infusoria are usually soft and delicate. Some of them are so flexible, that they can double and twist themselves almost as well as a worm can writhe. Others are hard, and some are covered by a transparent case secreted from their own body.

This case is called a *lorica*, and is used as a shelter for the soft and otherwise defenceless animal. When frightened, such forms quickly withdraw themselves to the bottom of the lorica, and remain there in a little, almost shapeless, heap, until the danger is past. Then the enclosed Infusorium will slowly rise to the front of the lorica, protrude the front part of the body, open the organs by which it creates currents in the water, and there fish for the food that those currents bring to its mouth. These loricæ are usually permanently attached to plants or to other submerged objects. They are generally transparent and colorless, but sometimes, as they become old, the color changes to a rich, translucent chestnut-brown.

In other Infusoria, the loricæ are not hard and transparent, but soft and opaque, yet delicate. These are usually made of innumerable little particles of extraneous matters, fastened together by a sticky substance secreted from the animal's body. Almost any small particles floating about and striking against the sticky mass will be pretty sure to adhere, and so help to build up the soft sheath that serves the Infusorium as a protective covering, and sometimes effectually conceals it from the microscopist who may be seeking it.

But these soft and granular loricæ are not formed entirely by accident. They are built chiefly of those little particles brought to the animal by the currents produced by the organs which it has for that purpose. These currents contain the food that the sedentary Infusorium cannot go to seek as the free-swimming kinds can go, for the loricæ-building animals are almost as permanently fastened to their loricæ as is a snail to its shell. Sometimes the Infusorium will leave its home when the water has lost most of its oxygen, and the poor thing is nearly smothered, but it leaves the house only to die. Yet it generally prefers to die at home, for when the time comes, the little creature retires to the bottom of the lorica, contracts itself into a heap, and quietly goes to pieces.

There are also some Infusoria that form loricæ and are still free-swimming, carrying the house about with them. They likewise retire to the rear when frightened, and some even carry a little piece of hard substance on the front of the body, with which they plug up the entrance, and so make all secure.

There are still others that form a stem, with branches like the trunk and limbs of miniature trees, the colorless animals being fastened to the ends like so many leaves. In some of these, the animals when frightened can contract themselves into little balls; in others the branches contract into coils and withdraw the animals from harm; in still others, the whole tree-like colony, stem, branches and animals, contract and huddle down against the plant to which the stem is attached. And in still others, the *Vorticéllæ*, there is but

a single stem with a single bell-shaped body on the end, but the stem contracts into close spirals and suddenly draws the animal down. When the danger is past, the stem slowly uncoils, the branches spread themselves, the animals expand, and all is well. The variety of form and of habit in the Infusoria is exceedingly great.

The general opinion is that "animalcules" have no color. This is a mistake. The majority, it is true, are almost colorless, but green, crimson, yellow, indigo-blue or almost black Infusoria are not uncommon. The loricæ often become brown with age.

The free-swimming Infusoria are more abundant than the attached or sedentary forms, and much more difficult to examine, because they never stand still.

But how do these creatures, all of which are invisible without the microscope—how do they move? For this purpose they have organs of two kinds, and they are separated into two great classes according as they possess the one kind or the other.

In some there are one or more long, colorless lashes that extend from the front of the body, beat against the water, and row the animal about with great rapidity. Each of these lashes is called a *flagĕllum* (plural *flagĕlla*). In others, there are on the body short, fine hairs, that are continually vibrating and so rapidly that they are often invisible even under a high-power objective. The short hairs are called *cilia*, and it is their action on the water that urges the animal about even more quickly than that of the flagella.

These cilia may be confined to a circle around one end of the body, or they may be on the lower surface only, or the entire animal may be covered with them. Infusoria with cilia are more numerous than Infusoria with flagella. They are, however, not the only ciliated animals. The Rotifera are well supplied, and certain small aquatic worms have the entire body ciliated.

Although the Infusoria are so abundant that scarcely a drop from any pond or ditch can be examined without exhib-

iting some, the beginner will, the author fears, have some trouble in studying them, they are so lively and so small. The stage of the microscope must be kept in continuous motion to counteract the motions of the Infusorium and to keep it in the field, so that it may be seen as anything more than a whirling speck, and high-powers are needed to examine it. But the reader's object will be gained, if he learns to know an Infusorium when he sees one, and if he learns the name of some of the largest and the most common.

Many may be seen with a one-inch objective, but to ascertain whether any special one has cilia or flagella, may demand a $\frac{1}{5}$ inch of a higher-power objective, and unless this point is positively decided, the Infusorium cannot be identified. But "it is only the first step that costs." Any work or any study is always hardest at the beginning. When the student has identified one Infusorium, he will have little trouble with what comes after. The attached forms will not be difficult even at first, if a sufficient magnifying power is used, for since they are fastened by stem or by lorica to another object, they may be examined at leisure.

None of these delicate creatures can be well preserved as permanently mounted objects. Many chemical solutions and mixtures have been recommended for killing and keeping them, but few of the available ones are satisfactory, the soft bodies going to pieces, and melting away almost as soon as after a natural death. Osmic acid acts well, but it is so expensive (two dollars for fifteen grains), that few of us can use it.

If the observer is greatly annoyed by the incessant movements of the free-swimming forms, and desires to see how they look when quiet for a moment, the following solution will help. It answers the purpose well in some cases, while in others it is worthless. It always kills, but does not always preserve even momentarily after death. It is used by allowing a small drop to run under the cover-glass, and to mingle with the drop of water containing the Infusoria.

To a half-drachm of water add as much iodide of potassium as it can be made to dissolve, and to this saturated

solution, add as much iodine as the solution can be forced to dissolve. This ends the druggist's part. It remains for you to add enough of the solution to clean water, to make the color a rather deep amber. The proper strength can be learned only by experiment. If it kills, and destroys too quickly, add more water; if it does not kill quickly enough, drop in a little more of the iodine solution.

A method of restraining the movements of these active creatures has been discovered by Eismond, a European observer, and is said to be eminently successful. The writer has not tried it, but one of his friends has done so, and has reported enthusiastically in its favor.

To the water containing the Infusoria on the slide, Eismond adds a drop of a thick, watery solution of cherry-tree gum. This has no bad effect on the Infusoria, as all their vital processes can be satisfactorily observed, but the Infusoria themselves are practically imprisoned, being unable to change their position, while their cilia and flagella continue in active movement.

Mr. Henry C. Wells, not finding the cherry gum for sale in New York, visited a cherry tree, and from the trunk cut a piece of the exuded gum about one-third of an inch square. This he boiled in a test tube, making the solution thin. It remained unchanged and in good condition for several months. He uses it as recommended by Eismond. He says: "The flagella of the smallest of the Infusoria and the cilia of others, become very conspicuous, and as their progress is so greatly retarded, a careful study of their organization can be made."

Although it is scarcely possible to preserve the majority of the Infusoria as permanently mounted objects, it is still possible to preserve them alive pretty successfully and for some time, and to prepare an aquarium in which they will thrive through the winter, and give the microscopist an ever-changing supply.

A specie-jar, or a glass fruit-dish, makes a good microscopical aquarium, into which the gathering may be poured, and the contents left to themselves. A piece of glass should

be placed over the mouth to prevent evaporation, although this is not strictly necessary. Such an aquarium presents a wide surface to the air, it is so shallow that its microscopical contents may be readily captured, and it occupies less space than the ordinary vessels offered by the dealers. The writer has been in the habit of selecting such jars as could be bought for from ten to fifteen cents each, several of which may be used at once for purposes of experimentation, or for the cultivation of different classes of microscopic animal and vegetable life. Such an aquarium, if kept near a north window, will thrive all winter, giving the microscopist a continuous supply of interesting living objects, not necessarily confined to Infusoria, but, if he wish, embracing many groups of other microscopic creatures.

If the vessel of pond water be left near the window for a few days, the Infusoria will increase in a surprising manner. But the bottle's contents should be examined immediately, for although many forms that will not be in the gathering when first made will develop there in a short time, others will die and melt away almost as soon. The collection should therefore be examined with the microscope as soon and as often as possible, for the peculiar rule is, that certain animal forms will abound and flourish for a while, seeming to appear suddenly, only to vanish as suddenly, to give place to others of different form, character and habits. The food-supply acceptable to one kind may become exhausted, and the environment agreeable and beneficial to that form may become so changed, that some are killed, either by starvation or else by unpropitious surroundings, while there may be present an abundance of nutriment specially needed by the other kinds that so speedily succeed those that have died; the diffluent bodies of the latter may furnish the food demanded by their successors. Why one class will die out to be followed by another, cannot be positively known. The fact, however, remains, and the microscopist in order not to lose some rare or interesting creature, should not only examine the gathering as soon as possible after making it, but at frequent intervals

as it stands on his table, in the miniature aquarium near his window.

A north window is the best place for the aquarium, because the light from that part of the sky is more diffused and more even in quality. Direct sunlight will surely kill the Infusoria, as well as much larger and presumably more hardy aquatic creatures. After a microscopical collecting trip, never place the bottles in the sun for any length of time, and never allow direct sunlight to shine upon the microscopical aquarium.

The microscopical aquarium must be properly made if microscopic life is to be the object of research. A vessel of clear water will not amount to much. If Infusoria, or Algæ, or Rotífera, or worms, or any other kind of life is to develop in these jars, the spores or eggs must first be there, food must be readily accessible to the voracious creatures, and their native habitat must be imitated as nearly as possible.

All this can be done by transferring a small part of the pond or pool or ditch to the aquarium on the table. Do not act as the author has known some collectors to act, and carefully reject all water-soaked twigs and pebbles, and fronds of *Lemna*, and bits of aquatic plants, and pieces of decaying leaves. These things are often the most valuable in the collection. The little sticks may bear beautiful colonies of sedentary Infusoria, that often lead a roaming life while young, only to settle down in some pleasant place when they have arrived at hours of discretion, remaining in that spot permanently, or until the microscopist dislodges them or some aquatic animal swallows them, or until they accomplish their life-work and die. A pebble may be a nugget of microscopical richness.

Aquatic plants, especially those like *Myriophyllum* or *Utricularia*, whose leaves Nature has cut into numerous, almost thread-like divisions, are capital places to search for those animals which live in colonial clusters attached to submerged objects; and the rootlets of *Lemna* are almost as sure to be well supplied with these colonial or communistic groups. The decaying leaves are always abounding in infusorial or other

microscopical organisms, or they carry the germs that shall develop, or they may supply by their disintegration an abundance of food. Take all these things for the specie-jar aquarium, using judgment as to size and quantity.

When the jars have been standing in the window for some weeks, their sides may gradually become obscured by the growth of an amorphous vegetable matter that will be exceedingly annoying to the microscopist, as it will conceal all within the vessel, and a promising bit of weed, or a little swimming creature may escape capture, because the dipping tube cannot be properly directed. The difficulty is easily overcome. With a small sponge tied to the end of a stick gently rub the growth from the glass, and allow it to form a part of the food-supply of the microscopic animals within the aquarium. The deposit is not entirely the evil that it at first appears to be.

When the collector is gathering aquatic plants for the aquarium, and for the purpose of examining their stems and leaves for the microscopic animals that they may be carrying, he should not lift them from the water, since that movement often dislodges the adherent creatures and washes them away beyond recovery. A better plan is either to scoop a mass of plants into the dipper, there selecting the parts desired, throwing out those discarded, and gently pouring the water and the acceptable portions into the waiting bottle; or else the wide-mouthed vessel may be partly submerged and the plants gently floated into it. The former plan is perhaps the better, since any animals that may be washed from their moorings will remain in the dipper, and be transferred with the water to the collecting-jar.

No pond whose surface is mantled by a layer of *Lemna* should be passed without a sweep of the dipper. The little fronds and their delicate rootlets harbor many a curious creature. No slow stream where *Myriophyllum* abounds should be neglected. Those feathery leaves are the favorite resorts of sedentary Infusoria, and agile Entomóstraca. The hornwort (*Ceratophyllum*) is likely to prove a valuable acquisition, but

one that is usually less abundantly productive of microscopic supplies than *Myriophyllum*. *Utricularia* may also be examined with some probability of success, although it is usually the most disappointing of all the water-plants with divided leaves, probably because it has itself the habit of feeding upon any small animals that may venture too near that valvular entrance to its utricles. *Elodêa Canadênsis*, "water-weed," as it is often called, is not usually a good hunting ground for sedentary Infusoria, neither is the lower surface of the water-lily leaves. Both are always sought by the microscopist when searching for certain other forms of microscopic life, worms for instance, or *Hydra* (Chapter VI), but they are commonly disappointing when Infusoria are the objects sought. It is not the plant so much as it is the favorable surroundings, the abundance of food, the proper proportion of light and of warmth, the generally propitious environment, that attract the small creatures.

An old and water-soaked log, or a partly submerged and decaying plank, are hailed by the microscopist with delight, since they always prove to be treasures when Infusoria are not desired. When they are wanted, the old log and the rotting plank are of but little value. It is then usually a waste of time to scrape their surfaces. If you want aquatic worms these are the places in which to find them. If you want certain *Polyzoa* (Chapter IX), these are the best of good places in which to find them; but for Infusoria go elsewhere.

A shallow pool whose bottom is covered with last year's dead leaves, is commonly well supplied with free-swimming animals, and some of the bottom should be scooped up in the dipper and taken home to the aquarium. Any pond whose surface bears much *Lemna* is also the haunt of many of the free-swimming Infusoria.

The most prolific places, however, are those little ponds fed by slow springs at the bottom, or filled by freshets from a creek or other stream, and for the rest of the year land-locked, shaded by trees and bushes, protected from too rapid evaporation by a coating of *Lemna* fronds, and filled with *Nymphæa*

(candock), and *Utricularia*, and perhaps *Myriophyllum*, although these are not common in such places. The shade should not be too dense, nor the sunshine on the surface too bright; the proper conditions can be learned only by experience and by experiment.

In such a pond the free-swimming Infusoria will abound, or its water will prove prolific if kept in the small aquarium. These are the places too for *Chætónotus* (Chapter VII).

Those temporary pools, so often found by the side of country paths in the early spring, formed by the warm rain collected in little hollows where the leaves have been lying all winter, and which dry away almost before the new leaves have sought the sun, those shallow little lakelets are often wondrously rich in forms not to be found elsewhere at any other time of the year. They should never be passed without taking a dip. While the surface is still filmed with ice, such water may teem with animal life, just such life as the microscopist desires.

It is not possible to point out the exact locality where an abundance of microscopic animals may be found. They appear to be a law to themselves. The pond that may seem a likely place, may for some unknown reason be barren; while another to all appearance worthless may prove of great value. The food-supply may be the cause, or the temperature, or freedom from enemies, or some other thing. The microscopist can take his dips to the instrument, only hoping that he has the success for which he has wished.

There is one place, however, to which he need never go. This is the thick mud at the bottom. Here some Rhizopods may be collected, but Infusoria and other creatures rarely. They prefer to wander among the leaflets of the aquatic plants, to swim in the clearer depths, or to seek their smaller prey nearer the surface. Some forms of Rhizopods can be taken only nearer the surface among the plants. To carry home a bottle full of mud-and-water with nothing else is commonly a useless labor. Rather thrust the dipper among the aquatic weeds, and after several gentle turns and twists to loosen the

plants and to stir up the water about them, transfer the dipperful to the bottle, and hope for the best. The majority of microscopic animals may be collected in this way better than in any other, except by washing the plants and preserving the rinsing; but this is a rather more laborious method, and takes rather more time, a matter of some importance if the microscopist's leisure is limited. These methods, however, are not restricted to Infusoria.

In my vicinage, certain ponds with which I am well acquainted are always entirely free from *Lemna* and *Spirodela*, while others, smaller and shallower and within half a mile, are sure to be densely and completely covered by a mantle of these plants. From the first-mentioned ponds, the aquarium may be made by any of the preceding methods; with the others another method is advisable.

This manner of preparing the microscopical aquarium for the winter is trustworthy and easy, and imitates more closely than the specie-jar arrangement the course of nature under the open sky, and it is, furthermore, much less likely to collect the molestful and insufferable snail. It is only to cover the water with the *Lemna* and the *Spirodela*.

Skim off the thick stratum formed by these fronds, but without removing them from the water, and without allowing the water enclosed by their rootlets to drip from them. Add water from their native pond, and transfer them to the microscopical aquarium. Use no other plants, unless *Wolffia Columbiana*, the smallest flowering plant in the world, is obtainable. But *Wolffia* is not common, yet where it does occur, it is usually present in profusion, when it floats on the water like a green scum.

A single frond of *Wolffia* is only a little, green, globular grain, without even a rootlet, and varying in diameter from the $\frac{1}{50}$ to the $\frac{1}{35}$ of an inch. It is useful in the microscopical aquarium chiefly for the purpose of retarding the surface evaporation, although it possesses several structural features of interest to the microscopist.

Notice the hexagonal cells that together form the neat and attractive cuticle.

Notice the absence of the crystals which are so numerous in *Spirodela*, where they exist in two forms, the needle-shaped raphides, and the spherical sphæraphides, composed of aggregated small crystals, the tips of which project and roughen the surface, each compound crystal here, as in most other plants in which they occur, being enclosed within a special cell of its own. Both forms are plainly visible with the one-inch objective, after the *Spirodela* has been crushed in a drop of water, and the crystals have been dislodged from their resting places in the tissues.

Notice in *Wolffia* the breathing-pores (stomata) near the margin. These vary in number from one to six. Generally in the specimens from my locality I have found only three.

The hard little grain will reveal none of these secrets until it has been crushed and flattened under the cover-glass.

With the aquarium prepared in this way, the reader may feel sure that he has a rich and valuable gathering of microscopical plants and animals, that will live and thrive there for a pleasing length of time.

To prepare a slide for examination, remove a little mass of the mingled plants not larger perhaps than a grape, and catch in a watchglass the water that will drip from them. Against the side of the glass gently press the little mass to dislodge the entangled objects, and over it then pour water drop by drop from the dipping tube, and press it out, thus washing away any good things that might otherwise remain.

In half a teaspoonful of water thus obtained, I have had vigorous and beautiful representatives of almost every class of microscopic aquatic animals and plants, in great variety of species and of form; an embarrassment of riches.

Although most of these little aquatic creatures are voracious feeders, and while some flourish in putrid animal-macerations, the greater number seem to avoid filthy places. A pond contaminated by offal or by the refuse of the city's garbage will not be a good collecting-ground, unless the filth is greatly

diluted. Water that is offensive to the human being's sense of smell will not, as a rule, contain many animals. A few of a certain kind, those peculiarly and emphatically scavengers, will be there, but the collector will have a better chance for success, at least so far as species are concerned, in a sweet, clear-water pool where the weeds are profusely growing, where the trees drop their foliage in the autumn, and shade the surface in the summer; where the lilies bloom, and their leaves die, and by their decay supply food to the invisible animalcules in the shallow depths below.

A pocket-lens has been recommended as helpful in collecting creatures for the microscopical aquarium. Nothing could be more useless. With few exceptions, they are all invisible to any but a comparatively high magnifying power of the compound microscope. A pocket-lens will not exhibit them. A few are, in favorable circumstances, visible to the naked eye, but these are few. The microscopist that desires the little creatures must, through experience, know the favorable localities in his neighborhood; he must collect them aided only by faith and a tin dipper, and until he reaches his microscope, he can see them only by the eye of faith. Here the pocket-lens is a delusion.

There is an enemy to the microscopical aquarium that, when full-grown, is entirely visible to the unaided vision, and one that the collector should banish from his gatherings as speedily as possible. This is the water-snail. Carefully pick out every aquatic mollusk, and do it quickly, if you care anything about the welfare of the aquarium. Also search for those little jelly-masses in which the eggs are deposited, and eject them just as speedily. These hatch out in a warm room with surprising alacrity, and before the microscopist knows it, the aquarium will be swarming with the unwelcome little fellows, and they will do as their parent did; they will eat by day and and by night and go on forever, like Tennyson's brook.

They will flourish at the expense of the plants, which in a short time will be nothing but shreds and strings and decaying particles, while the aquarium will be abundantly supplied

with little, black cylindrical masses of snail excrement. If the plants are wanted in good condition and consequently the animals, carefully eject all the water-snails and their eggs. This may be done by a little daily attention for a short time, when there will be no further danger. If the eggs are allowed to remain, the young snails will soon have the upper hand, for they are too small and too easily concealed to be successfully contended with.

A small snail of the kind is peculiarly exasperating, as it is so minute that it is visible to the naked eye only in favorable conditions. It is a flattened coil, like the shell of the common *Planorbis*, and probably belongs to the same genus, but it measures only about $\frac{1}{40}$ inch in diameter. The damage done by its tongue (odontophore), is not great, being in proportion to its size, but its constant attention to the plants has effect. After the aquarium has been apparently freed of all the obnoxious snails, it is peculiarly annoying to see one or more of these little black dots clinging to the glass, and to know what they are doing. Another small nuisance of the kind is a snail of another genus, only about $\frac{1}{15}$ of an inch in length. Like every other coward, it takes advantage of its defenceless victims. For it there is only one remedy.

The shells of these unwelcome guests are rounded and amazingly slippery. To seize them successfully in the forceps is almost impossible, unless the sharp points pierce the shell. If they are crushed, and the soft body is left to decay in the water, the last state of the aquarium may be worse than the first. To put the hand into the jar may do more harm than good. Perhaps the best way in which to capture these obnoxious creatures, if they are too big to be drawn into the dipping tube, is to use the flattened end of a narrow strip of wood, and with it either lift them out, or gently to push them up the side of the aquarium until the finger can reach them.

These aquarium pests frequently carry commensal Infusoria. It is a pity to destroy them, but if they keep bad company, they must take the consequences.

When the microscopical aquarium has been standing un-

disturbed for a short time, a pellicle or thin film, visible to the unaided vision, forms on the surface of the water. To the naked eye this presents a somewhat greasy appearance, and reflects the light in a way that suggests an imperfectly polished mirror. The observer, looking through the side of the vessel and obliquely upward toward the lower surface of the water, will see distinctly this thin layer, and will also see that various minute objects are apparently attached or adherent to it. This pellicle or film is the mycoderma, and is present in nearly all such situations.

It is composed of various bacteria, fungi, microscopic plants and microscopic animals, all of which, especially the bacteria and the fungi, thrive there, multiplying and increasing wonderfully.

The mycoderma should not be neglected by the microscopist. Many of its constituent objects are minute, and capable of study by only high-power objectives, but others, equally interesting, are visible and as instructive and entertaining under low powers. A thin cover-glass touched to this pellicle will bring away innumerable specimens not so easily obtainable elsewhere, nor in so good condition. A cover-glass dipped beneath the mycoderma and gently lifted upward will gather a similar harvest, and after its lower surface has been wiped dry, may be inverted over a drop of water in a shallow cell, and there examined. This seems to be a complicated procedure, yet it is really easy and simple. The experiment will often repay the microscopist by the number and the variety of objects thus obtainable.

In this way, the writer has by a single touch gathered beautiful specimens of various Infusoria, Rhizopods, and Desmids, among them the most luxuriantly developed *Dendrómonas* that he has ever seen. There were literally hundreds of these Infusoria at the extremities of the profusely branching stalk, while representatives of other genera too minute or too uncommon to be here mentioned were almost as well developed and as abundant. An examination of the mycoderma will indeed reward the microscopist.

All the plants previously mentioned are useful in the microscopical aquarium, but *Myriophyllum* is the most desirable. It will thrive, and help the other plants as well as the animals to thrive. Its finely divided leaves afford shelter for innumerable forms of life. They are excellent places in which to seek for Diatoms and for various Algæ; among them may be found representatives of most of the fresh-water microscopic creatures, both vegetable and animal. *Utricularia* comes next, so far as desirability is concerned; after it there is little choice among the larger aquatic plants.

A Syracuse solid watchglass, covered by another of the same kind, forms an admirable and prolific secondary aquarium. A few leaves of *Myriophyllum* or other aquatic plant placed in the concavity, with Algæ or other desirable objects from the larger vessel, and a teaspoonful of water added, will prove a valuable source of supply, in which many desirable microscopic creatures will thrive and multiply. It should be covered to prevent evaporation, and be left standing on the table. It will take care of itself. When exhausted it is easily renewed, and in a short time will richly reward the microscopical student.

The following Key refers to only a few of the commonest Infusoria in fresh water, and in vegetable infusions. To include a tithe of those frequently seen in such places is impossible. When the microscopist learns that there are about seventy known species of *Vorticélla* alone, and about thirty of *Mónad*, he will perceive that it is possible to refer, even in the most superficial way, to but few of these abundant and attractive creatures.

Key to Genera of Infusoria

1. Free-swimming (*f*).
2. Not free-swimming; singly or in clusters on a stem (*a*).
3. Not free-swimming; in a transparent or a granular lorica (*b*).

a. Stem much branched, neither it nor the animals contractile. *Dendrómonas*, 1.

a. Stem much branched, both it and the animals contractile. *Carchésium*, 2.

a. Stem much branched, only the animals contractile. *Epistýlis*, 3.
a. Stem not branched, but contracting into a spiral coil. *Vorticélla*, 4.
b. Loricæ vase-shaped, transparent (*c*).
b. Loricæ soft, granular, brownish (*e*).
c. Attached to one another to form colonies. *Dinóbryon*, 5.
c. Not attached to one another (*d*).
d. Lorica without a stem; adherent by the narrow base; upright. *Vaginícola*, 6.
d. Lorica without a stem; decumbent; adherent by the broad side. *Platýcola*, 7.
d. Lorica with a short stem; upright. *Cothúrnia*, 8.
e. Extended animal trumpet-shaped. *Sténtor*, 9.
f. With one or more flagella at the front (*g*).
f. Without flagella, but with cilia (*h*).
g. Body very changeable in shape; colorless; one flagellum. *Astásia*, 10.
g. Body very changeable in shape; green or red; one flagellum. *Eugléna*, 11.
g. Body not changeable in shape; colorless, notched in front. *Chilómonas*, 12.
g. Body not changeable in shape; green; with a short, stiff, colorless tail-like projection. *Phácus*, 13.
g. Body not changeable in shape; green; united in a revolving colony. *Uvélla*, 14.
h. Cilia on the entire surface (*i*).
h. Cilia confined to the lower, or flat ventral surface (*k*).
i. Neck long, very elastic and extensile; colorless. *Trachelocérca*, 15.
i. Neck long, flattened, not extensile; colorless. *Amphiléptus*, 16.
i. Body brownish, slipper-shaped. *Paramœcium*, 17.
i. Body green, red, blue, or almost black; ovoid or trumpet-shaped; cilia largest on the front. *Sténtor*, 9.
k. Cilia large, few, scattered (*l*).
k. Cilia fine, numerous (*m*).

l. Body more or less circular in outline. *Euplótes*, 18.
l. Body more or less oblong in outline. *Stylonýchia*, 19.
m. Mouth followed by a conical tube of rods. *Chílodon*, 20.
m. Mouth followed by a brown, sickle-shaped membrane. *Lóxodes*, 21.

1. Dendrómonas (Fig. 106)

The stem is many times divided into numerous branches, and the branches themselves are also much divided, with one small Infusorium, sometimes two, at the end of each. The whole has a beautiful, but colorless tree-like appearance. The stem is often found attached to *Myriophyllum* and to other plants. The animals have each two flagella, visible only with a high-power objective.

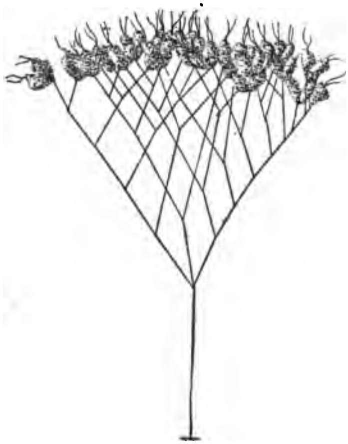


Fig. 106.—Dendrómonas.

There is no special mouth. A particle of food dashed by the flagella against any part of the body sinks into its soft side and is thus swallowed without a throat.

The whole colony is often more branched than is shown in the figure. It may be recognized with a good one-inch objective.

Each body is about 8 microns in length; the height of the colony is about 19 microns. There are two small contractile vesicles near the posterior border of each body. They are not easily detected.

2. Carchésium (Fig. 107)

The stem, attached to plants or to other submerged objects, is divided at the summit into many branches, with one Infusorium at the end of each, and many others scattered along them with shorter branchlets of their own.

Through the main stem and through all the branches extends a cord-like muscular thread, that suddenly contracts when the animals are frightened or disturbed, and pulls the entire colony toward the point of attachment to the plant. The branches may each contract one at a time, and draw its burden of infusorial fruit down to the main stem, without disturbing any other portion of the colony; or all the branches may contract at the same moment. While the individual animals are connected together, they are still somewhat independent of one another.

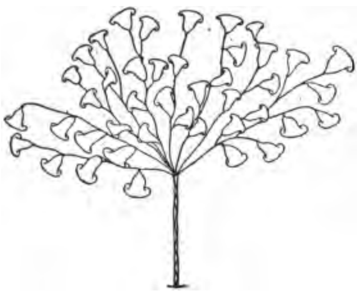


FIG. 107.—Carchésium.

The front border of each body is surrounded by a wreath of cilia, visible under a high power. These are the only cilia on the creatures. When the animal is contracted these vibratile hairs are folded together, each body then resembling a little ball. They vibrate rapidly, producing vortical currents that bring to the mouth any food particles that may be in the vicinity.

The entire colony is colorless. It may include as many as a hundred Infusoria on the branches. It can be seen with a low-power objective.

The separate and independent contraction of the branches and of the stem will distinguish it from all other tree-like Infusoria.

3. EPISTÝLIS (FIG. 108)

As in the two preceding forms, the stem of *Epistylis* is often much branched. The Infusoria at the ends of the branches can alone contract, as they often do with a jerk, settling back on their stalk as if they meant to impale themselves, or dropping and nodding like flowers fading on their stems. The bodies of the expanded animals are somewhat bell-shaped, their widest part being the free end, which closes when the body contracts.

The front border is encircled by a wreath of cilia, to be properly discerned only with a high-power objective. The one-inch lens, however, will show the rapid currents produced, because all small particles in their neighborhood are caught up and dashed around in the mimic whirlpool. The animals select from these streams anything that they may want, and let the rest sweep by; they have a distinct but usually invisible mouth near the center of the frontal region. The entire colony is generally colorless. It is often found attached to *Myriophyllum*, and to other plants.

One species, *Epistylis flavicans*, which, as its specific name indicates, sometimes has a yellowish tinge, often becomes so abundantly developed, not only in the microscopical aquarium, but in the ponds under the open sky, that its mass becomes visible to the naked eye, as a grayish film on the surface of the leaf or of the glass. I have had the species so plentiful in the aquarium that it formed a visible, gray ball a quarter of an inch in diameter. In such instances, the foot-stalk seemingly becomes weakened, for it falls against the supporting object, yet each animal continues to vibrate its wreaths of cilia, to contract the body and slip back against the end of the stem, and to perform its vital functions as perfectly as it performed them when it was elevated by a rigid pedicle. Notice, too, that the stem is hollow.

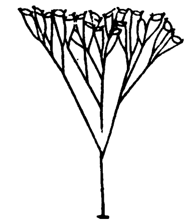


FIG. 108.—Epistylis.

The bodies of this decumbent variety are bell-shaped, conspicuously striated transversely, and are furnished with a ciliary wreath richly supplied with cilia, there being no fewer than five of these ciliary circles, perhaps six. Five are plainly visible, and may be seen with little difficulty, when the animal is in a weakened or a dying condition.

4. VORTICÉLLA (FIG. 109)

The unbranched stem of *Vorticélla* contains a spiral muscular thread like a thin cord, which with surprising suddenness

contracts into close coils, and draws the Infusorium down with it, the bell-shaped body contracting at the same time into a more or less spherical mass.

The *Vorticellæ* are common, scarcely a leaflet of any aquatic plant being without them. They are usually colorless, although green ones do occur. The body is more or less bell-shaped, the narrow part of the bell being fastened to the top of the contractile stem. The front border is surrounded by a wreath of fine cilia which need a high power to show them. These produce currents in the water similar to those of *Epistylis*, and for similar food-collecting purposes.

No *Vorticella* is visible to the naked eye. Yet not rarely it increases so rapidly, and forms colonial clusters so extensive, that the Infusoria become visible on account of the numbers in the group. They then appear as a little spot of whitish slime, or mucus, on the aquatic plant, or on the leaf in the aquarium, and at a jarring of the vessel, or at a touch of a needle-point to the spot, the mucoid drop may be seen quickly to become smaller, and to collapse against the supporting object. An experience of this kind always shows the student that he has a mass of *Vorticella*, as there is no other infusorial cluster that exhibits such shrinking at a touch or a shock, an action that is accomplished by the sudden and simultaneous coiling of each individual stem. There are some colonial Rotifera that often increase so rapidly in the aquarium that the mass becomes visible, and shrinks at a touch; experience only can teach the observer to diagnose such cases without recourse to the microscope.

These clusters of *Vorticellæ* are seldom noticeable at the moment of collection, as at the slightest touch or jarring movement, the little creatures collapse, while removal from the water also tends to make them less conspicuous. It is in the aquarium that they attract attention.

Such clusters should be separated with the supporting object, and gently transferred to the slip and to the microscope stage. A hasty movement may result in the loss of almost every body in the group, leaving only the

lone, partly coiled and dead stems. They must be treated tenderly.

Occasionally during the summer these colonies increase so rapidly that they break loose, and float on the surface. The writer has seen such a cluster in the middle of a pond, where it appeared like a spot of saliva, and was mistaken for that until, at a venture, it was skimmed off, when the microscope at home told the interesting story.

The contractions of the stem are surprising in their suddenness. While the observer is quietly gazing at the graceful creature whirling its cilia and making tremendous whirlpools on a small scale, it disappears like a flash, and the student feels like looking for it on the table. Presently it begins to rise slowly from the plant against which it was crouching, and the spirally coiled stem lengthens as it straightens. Frequently it is hardly extended before it again leaps out of sight, or close to the object that supports it.

FIG. 109.—Vorticélla.

This will probably be one of the first Infusoria to attract the observer's attention. He will consider it a wonderful thing, as it is. The figure (109) shows some extended and some contracted. They are often found in clusters, sometimes of a hundred or more, all bobbing and swaying in a laughable way, for when one contracts it usually sets them all off.

In the figure the contractile vesicle is represented by a small circle toward one side of the body, near the front. It is usually found with little difficulty, after the first one has been seen.

The great majority of *Vorticellæ* have the body-surface finely and transversely striated, ornamented by minute, rounded elevations, or by some other form of cuticular appendage.

Sometimes these transverse striations are coarse and conspicuous; usually they are so fine and so close together, that

to see them is often somewhat of a task for the observer's eye as well as for the objective, especially when the microscopist is searching for them for the first time. If the reader can see the finest and closest of these lines with ordinary, central illumination, he may congratulate himself upon the possession of a good objective, well corrected and well adjusted.

It is here assumed that the amateur microscopist will not be able to use an objective higher in power than a $\frac{1}{8}$ inch; he will probably have a $\frac{1}{4}$ or a $\frac{1}{5}$. If his objective is made by a reputable optician, and still fails to reveal these striations, he may justly conclude that his eye has not yet been sufficiently educated by microscopical work to be able to do justice to the object, and perhaps not to the objective. In minute investigations with the microscope, much depends upon the training of the eye. The veteran microscopist can easily distinguish minute objects in the field of view, that are absolutely invisible to the eye of the untrained and inexperienced observer. The beginner should remember this, when he feels disposed to criticise because he fails to see what others say should be visible.

At times, if these fine striæ are invisible when the objective has been focused on the body-surface, they may be seen by focusing on the margin of the body, where they will appear as minute, alternate ridges and still smaller furrows. In other instances they may resemble a row of exceedingly minute beads on the edge of the body.

The microscopist may take pleasure, and may feel happy in his success, if he can, with the $\frac{1}{5}$ inch objective, see these transverse striæ either on the surface or at the body-margin, without using oblique illumination. It can be done, and always should be done, by central light. If the reader should want a desirable object over which to exercise his skill, he will find it among the *Vorticellæ*.

To obtain the oblique illumination, the mirror should be slightly tilted, or swung to one side, so as to throw the light across the body of the animal, instead of directly and centrally through it. This causes the minute elevations on the surface

to cast a shadow, which accentuates the ridge as well as the furrow. The well-informed microscopist never voluntarily uses oblique light when he can avoid it. In fine work with many Diatoms, oblique light is necessary, but it is rarely used intentionally in the study of living creatures.

If the reader fails to see these delicate transverse markings, he should not be hasty in deciding that he has found one of the *Vorticellæ* with a smooth surface, for the chances are that he has not. Of the seventy known species, only twenty-one are recorded as having a smooth cuticle.

The seven following species are here introduced, not only because they are rather frequently met with by the active and vigilant microscopist, but chiefly on account of a special and peculiar interest inherent in each. Two, *Vorticella rubri-stígma* and *V. limnêtis*, are selected because they are members of the uncommon group of *Vorticellæ* with a smooth surface; another, *pusílla*, because it is nearly the smallest *Vorticella* yet observed, as its expanded body measures only 19μ, or about $\frac{1}{1300}$ inch in length; another, *smarágdina*, on account of its beautiful, translucent, emerald-green color, a tint that pervades the entire substance of the body, but not the stem; and the remaining three, by reason of their characteristic surface-ornaments or investment.

As a rule, the contractile vesicle in *Vorticella* is single, but in *V. vestíta*, *V. rhabdóphora* and *V. moniláta*, it is double. In each of these species, there are two contractile vesicles, the one usually situated directly opposite the other, at a different level, the two pulsating alternately; but unless the body is in a certain position, only one is visible, as the one obscures the other, the lower being so far beyond the focus of the objective that it is not noticeable. The presence of the two is interesting and note-worthy, because they have thus far been discovered only in those species that possess some form of surface investment, or ornamentation, other than transverse striæ.

These double vesicles in *Vorticella* are not easily seen; the seeing of them is distinctly difficult, but the deed is worth

the doing. The observer that can sit quietly, and view at his leisure the alternate throbbing of these little organs, may felicitate himself, and may forgive himself for feeling elated, if not proud.

The nucleus is a long, narrow band, curving across the front of the body, or the middle region, and in some species extending along one side nearly to the posterior extremity. Usually it is plainly visible, especially when the *Vorticella* has been weakened by ill health, or by prolonged confinement under the cover-glass.

The *Vorticellæ* themselves are easily recognizable. The following Key leads to some of the interesting species.

Species of Vorticélla

1. Surface transversely striate only (*a*).
1. Surface conspicuously clothed or ornamented (*b*).
1. Surface smooth (*c*).
   - *a*. Body coloriess, very small (19μ), conical-campanulate (long bell-shape), *pusílla*, 1.
   - *a*. Body translucent emerald green, conical-campanulate, *smarágdina*, 2.
   - *b*. Body with a lace-like coating of small cells, *vestíta*, 3.
   - *b*. Body with transverse rows of conspicuous, bead-like elevations, *moniláta*, 4.
   - *b*. Body with mucilaginous coating containing many fine, linear (bacilliform), rod-like bodies, *rhabdóphora*, 5.
   - *c*. Body conical-campanulate; muscular thread of the stem with numerous red points attached, *rubristígma*, 6.
   - *c*. Body conical-campanulate; no red points in the apparently twisted stem, *limnétis*, 7.

1. Vorticélla pusílla

The body of this little *Vorticella* is rather less than twice as long as it is wide at the widest, anterior border, from which it tapers to its point of attachment to the stem. When it contracts, it becomes nearly spherical. The extended stem

is from five to six times as long as the expanded body, but that is only about $\frac{1}{1300}$ inch (19μ) in length.

It usually lives alone on the rootlets of *Lemna*, or it is attached to other fine filaments. It is interesting and worthy of special attention chiefly because it is so small.

2. Vorticella smarágdina

This, the only green *Vorticella* on record, may be readily recognized by the characteristic color. It sits at the summit of its colorless stem like a living emerald, translucent, beautiful. It is found sometimes alone, sometimes a few together in a group.

3. Vorticella vestíta

The wonderful surface-coating of cells makes this species recognizable at a glance and at the first meeting. The cells are arranged in a single layer, and in nearly parallel series around the body. When the animal is in a weak or a dying condition, these become distended and bubble-like, the *Vorticella* then resembling a little mass of foam.

There are two contractile vesicles.

4. Vorticella moniláta

No extended description is needed to make this *Vorticella* recognizable; this is accomplished by the rounded, bead-like elevations that adorn the surface, and are arranged in close, ring-like series around the colorless body. On the front border they are usually larger than they are elsewhere.

This species has at times developed so plentifully in my microscopical aquarium, that I have had a colony formed, by actual count of two hundred members, another of eighty-three, while smaller groups were common.

Each body has two contractile vesicles.

5. Vorticella rhabdóphora

The surface is finely striated transversely, and clothed with a delicate, mucilaginous coating, crowded with short, slightly

curved rod-like bodies, that, when seen "end on," or in optical section, appear like minute granules. These rods are only about $\frac{1}{12000}$ inch (2μ) in length. They are slender and delicate.

The body is usually attached obliquely to the stem, which is less than twice its length.

There are two contractile vesicles.

6. VORTICELLA RUBRISTÍGMA

The absence of transverse striæ and of other surface markings, together with the presence of numerous little red points on the muscular thread within the sheath of the stem, at once make this *Vorticella* known as the species with the red-speckled stem (*rubrìstigma*). The body is less than twice as long as wide; the stem nine times the length of the expanded bòdy.

7. VORTICELLA LIMNÉTIS

The smooth surface, the absence of all cuticular markings or ornaments, and the apparently twisted sheath of the stem, taken together characterize this species. It is about $\frac{1}{500}$ inch (50μ) in length, the stem from six to seven times as long.

5. DINÓBRYON (FIG. 110)

In the early spring, as early as March, among the Algæ then found so abundantly in shallow pools, colonies formed of small, vase-shaped loricæ often are obtained. They are sometimes attached to a plant or to a filament of Alga, or as often float freely through the water, as they are fastened to the support by a slight tenure, and are easily detached.

The loricæ are transparent and colorless. They may be overlooked, but the Infusorium within each one is rather conspicuous to even a low-power objective, for it has a narrow green band on each side of the body, and often a minute, red eye-like spot in the center of the front border. The loricæ are united together into colonies by the attachment of one or two sheaths to the front edge of the one behind, until branching clusters of some size are formed. Each lorica is about 20 microns in length.

The front border of each enclosed Infusorium bears two flagella, one long, one short. These are seen with difficulty even with a moderately high-power objective. The lashing of all the flagella in a large colony urges it rapidly through the water, after it has been freed from its supporting plant, and is freely floating.

According to my experience, *Dinóbryon* is seldom found in the summer. I have only once obtained a single specimen from an open pond during the last week in October.

FIG. 110.—Dinóbryon.

6. VAGINÍCOLA (FIG. 111)

The lorica is colorless, transparent, and about three times as long as broad. In form it is long vase-shaped, or sometimes nearly cylindrical; the base, or the part fastened to the plant or other object, is usually rounded.

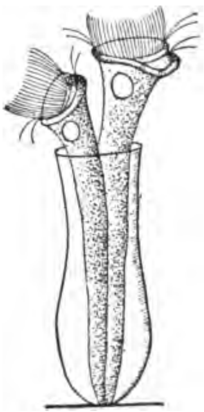


FIG. 111.—Vaginícola.

The animal, when it projects, extends for a considerable distance beyond the opening at the front of the lorica. When frightened, or disturbed in any way, it quickly closes its broader front part, and retreats as far into the sheath as is possible. When recovered from its fright, it slowly ascends to the opening, expands itself and resumes its fishing operations. It is fastened to the extreme end of the lorica by the tip of the body; from the sides it is entirely free.

On its front border it has a wreath of fine cilia in continuous motion when the animal is extended. The body is soft and flexible. It is sometimes of a pale greenish tint, but the

lorica, so far as the writer has observed, seldom changes color even with age.

It is not uncommon to find two bodies in one sheath, where they seem to live together in peace and harmony. This may be an advantage to both, for two wreaths of cilia can produce stronger currents, and bring more food to the mouth of the always hungry creature. *Vaginícola* is common on *Lemna* and on *Myriophyllum*.

Length of lorica 125 microns.

The small ring in the front of each body in the figure represents the contractile vesicle.

7. Platýcola (Fig. 112)

The lorica is flattened, and is in outline almost circular when seen from above. It is always adherent to some submerged object by the broad, flat side; the opposite or upper surface is convex. The opening, through which the animal extends itself, as in *Vaginicola*, is at one end, and is often prolonged into a short neck. The figure shows a side view with the animal extended.

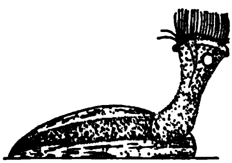


Fig. 112.—Platýcola.

When young, the lorica is colorless, but it soon changes to a deep brown, often becoming so opaque that the body of the Infusorium cannot be seen through its walls.

The body itself is usually colorless. It is attached by its tip to the side opposite the mouth of the lorica. When frightened it darts back into the sheath as *Vaginicola* does. Two animals are not seldom found in one lorica. It is not uncommon on *Myriophyllum* and other aquatic plants. The length of the lorica is about 90 microns, or $\frac{1}{277}$ inch.

The contractile vesicle is apparent, often conspicuously so, at the side of the neck, at a short distance behind the front border. It discharges its contents into the animal's throat (pharynx).

8. COTHÚRNIA (FIG. 113)

The observer may at first mistake this for a small *Vaginícola,* as the loricæ of both somewhat resemble each other in shape; but *Cothúrnia* can always be distinguished by the little stem or foot-stalk, that lifts it for a short distance above the plant to which it is attached.

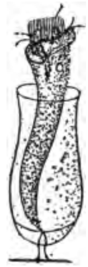


FIG. 113.—Cothúrnia.

This foot-stalk in some species is very short, and must be especially looked for; in others it is somewhat conspicuous.

The lorica is vase-shaped, often with the sides variously curved. It changes to a brown color as it grows old.

It is smaller than *Vaginicola,* and more delicate in appearance. A species frequently seen has the lorica about $\frac{1}{480}$ inch, or 52 microns in length, while that of the common form of *Vaginicola* may be about $\frac{1}{200}$ inch or 125 microns.

FIG. 114.—Sténtor polymórphus.

Cothúrnia is not rarely found attached to the Entomostracans, *Canthocamptus* and *Cyclops* (Chap. X). It thus secures free transportation, and rapid transit to richer and more varied sources of food-supply.

The body of the enclosed Infusorium is not colored. In its action it resembles *Vaginícola* and *Platycola,* being similarly attached to the posterior end of the lorica, and having a similar circle or wreath of cilia around the front border. Two animals are sometimes found in one lorica.

9. STÉNTOR (FIGS. 114, 115, 116)

The *Sténtors* vary somewhat in shape in the same species. The bodies of all are at will somewhat changeable in form. The largest are trumpet-shaped, and are, as a rule,

permanently attached to some object by the narrow end of the body. They also commonly form a soft, brownish, granular sheath or lorica, to the bottom of which they retreat when disturbed, folding together the wide trumpet-shaped frontal border.

The entire surface of the body in all the species is ciliated, but the cilia are small and fine. Around the edge of the anterior border is a circle of longer and larger vibratile hairs, visible with a moderately low power.

The *Stentors* are common. The following Key will help the observer to recognize some of those most frequently seen.

Key to Species of Stêntor.

1. Attached; trumpet-shaped, often forming a short, soft granular sheath (*a*).
2. Free-swimming; more or less ovoid; green, red, blue or almost black (*b*).

a. Body large, often 1250 microns in length, trumpet-shaped; greenish; often without a visible sheath, and when one is formed it is sometimes soon abandoned, the *Stentor* then swimming freely. The body is slightly changeable in shape. Several *Stentors* of this species are often found close together, having formed in common a soft sheath divided into irregular compartments, one for each Infusorium. *S. polymórphus*, FIG. 114.

a. Body long, and narrowly trumpet-shaped, the frontal region divided into two lobes, one of which is almost at a right angle to the other. The body has many long, fine, stiff hairs (setæ) projecting from it, and visible under a high-power ($\frac{1}{5}$-inch) objective.

The sheath is always present. It is narrow, cylindrical, brown, and about one-half as long as the extended body.

This *Stentor* is never free-swimming, and is never found in company with others of the same species. It is not uncommon on *Myriophyllum* and on other aquatic plants. Length of body about 1000 microns. *S. Barrêtti*, FIG. 115.

b. Body green or red, the red color often limited to the part just beneath the wide frontal border, where the circle of large cilia is situated. Sometimes the red color is diffused over the whole body, but usually the green matter so obscures it that it remains invisible unless specially looked for.

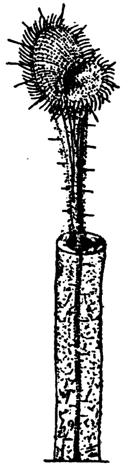


FIG. 115.—Sténtor Barrétti.

This species is often extremely abundant at the bottom of shallow ponds in early spring, and among the aquatic plants. The animals are often so plentiful that I have several times had them form a visible, green film on the side of the microscopical aquarium. The green color then always entirely conceals the red. *S. igneus*, FIG. 116.

b. Body large, indigo-blue. This in shape when extended resembles FIG. 114, but is much smaller. When contracted it is not unlike FIG. 116. Very common in some localities. *S. cœrûleus.*

b. Body dark brown, almost black. This in form likewise resembles FIG. 116. Common. *S. níger.*

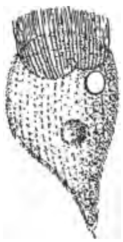


FIG. 116.—Sténtor igneus.

FIG. 117.—Astásia.

10. ASTÁSIA (FIG. 117)

Body long, narrow, and colorless; exceedingly soft, and changeable in shape, altering its form as it glides over the slide, as it does rapidly. It has one long straight flagellum at the

front. It is common, but may be overlooked by reason of the absence of color, and its small size. It has a distinct mouth followed by a distinct throat (pharynx), but these are small and not easily observed. The contractile vesicle is near the front border. It is minute.

11. Eugléna (Fig. 118)

Body long and rather narrow, widest in the middle and tapering to both ends. It is exceedingly changeable in form, and bright green or red in color. The front end may be seen with a high power to be notched as if the Infusorium had two lips, the long, vibrating, colorless flagellum appearing to issue from the notch.

There is sometimes a small red spot near the front end. It is supposed to be an imperfect eye. It is often absent from an old *Euglêna*.

At the posterior end is a short, pointed, stiff, and sometimes curved tail-like prolongation. This is usually colorless.

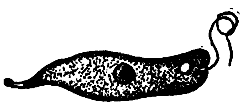


Fig. 118.—Eugléna.

The Infusorium is common, occasionally occurring in such numbers that it tinges the water green.

As it grows old, its color changes to a bright red, and in that condition it has been described as another species and has received another name.

This crimson *Euglena* is supposed to have been the cause, by its miraculous increase, of one of the Plagues of Egypt, in which the water was turned into what appeared to be blood.

The flagellum is often lost, a fact that at first may give trouble in the identification of the animal.

Euglena is rather slow in its movements.

12. Chilómonas (Fig. 119)

This colorless little creature is common in vegetable infusions. It may be recognized by the notch at the widest or front end, and the curve of the back which makes it look almost hunchbacked. Under a high power it shows two flagella, one

of them throwing itself into a coil or loop when the Infusorium settles down to rest, as it frequently does.

The animal's movements are rápid and difficult to follow, especially when it is well supplied with food, and is thriving amid decaying Algæ or other aquatic plants. While hurrying through the water, it suddenly stops, and fastens itself to the slide by coiling one of the flagella and thus anchoring itself to the glass.

It increases rapidly by longitudinal division.

I have seen these Infusoria so profusely developed in a microscopical aquarium that they formed a great white cloud

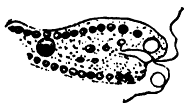


FIG. 119.—Chilómonas paramæcium.

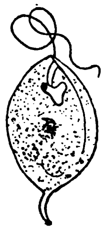


FIG. 120.—Phácus pleuronéctes.

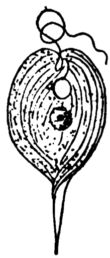


FIG. 121.—Phácus longicaúdus.

visible to the naked eye, and that rose and fell and glided through the water in graceful curves and undulations. As the largest *Chilómonas* is only about $\frac{1}{600}$ inch, or 40μ, in length, this visible aggregation must have contained the animals in enormous numbers.

The body is abundantly supplied with small colorless discs that the iodine solution turns blue, showing that they are probably starch grains, or that they have a similar chemical composition.

13. PHÁCUS (FIGS. 120, 121)

The body of *Phácus* is flattened, thin, and rather like a small leaf. It is widest in front and usually rounded. It tapers from the center to a short, pointed, colorless tail-like prolongation.

At the broad end it has one long flagellum, often difficult to see.

There are in our ponds, several species, all of which are green.

1. Body not twisted at the rear; tail short, curved. *Ph. pleuronéctes*, FIG. 120.
2. Body twisted or not at the rear; tail long, straight. *Ph. longicaúdus*, FIG. 121.

14. UVÉLLA (FIG. 122)

The little animals forming these rapidly swimming and revolving colonies are united by their narrow ends into almost spherical microscopic masses, varying in each group from two or three up to forty or fifty, or even more.

FIG. 122.—Uvélla.

Each Infusorium has a narrow, yellowish-green band down each side of the somewhat egg-shaped body, and two long, fine flagella at the broader front end. The colonies are common in early spring, in shallow pools with Algæ.

Each animal has two contractile vesicles near the posterior end of the body. They are colorless, very small and not easily detected, but they are always present.

15. TRACHELOCÉRCA (FIG. 123)

This will probably be a greater surprise to the observer when he first sees it than any other common Infusorium, on account of the remarkable neck that can be stretched out to five or six times the length of the body, and drawn back until it almost entirely disappears. The body, without the neck, is somewhat spindle-shaped, and occasionally ends in a short, tail-like region.

The Infusorium is often concealed in a mass of fragments, or under a heap of refuse, with only that wonderful neck visible, stretching, bending, writhing like a colorless snake, as it

searches the locality for food. The end of the neck is pointed and bears the mouth at the tip.

While this manner of concealing itself is the animal's usual method, I have, on one occasion, found it appropriating the empty shell of *Difflúgia acumináta* to its own use. The body was visible through the shell walls, snugly ensconced within, and the neck had not changed its elongating and writhing powers. These were actively in evidence at the mouth of the shell. The excellence of the choice, and the seeming wisdom of the arrangement are apparent.

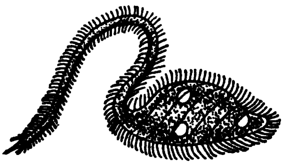


FIG. 123.—Trachelocerca.

The Infusorium is clothed with fine cilia, and is obliquely striated or furrowed in two directions.

It is comparatively plentiful among aquatic plants.

It has two, sometimes three contractile vesicles, as shown in Fig. 123.

16. AMPHILÉPTUS (FIG. 124)

This is one of the largest of the free-swimming Infusoria, sometimes measuring 1600 microns in length. The neck is not extensile as in *Trachelocerca*, although it is the longest part of the animal.

FIG. 124.—Amphiléptus.

The body, exclusive of the neck, is somewhat spindle-shaped, tapering more rapidly toward the rear than toward the front. The latter, or neck-like region, is flexible, and is capable of being turned and twisted about in a way that often suggests the movements of an elephant's trunk.

The whole body is covered with fine cilia.

The mouth is at the base of the neck, on the lower or ventral surface, and may be seen with little difficulty.

In the figure, the small circles near the back are the contractile vesicles; the moniliform chain near the middle is the nucleus.

17. Paramæcium (Fig. 125)

This is sometimes called the "slipper animalcule" on account of its shape. It is frequently found in the ponds, but is especially abundant in vegetable infusions. The hollow place resembling the opening in the slipper for the foot, is the part leading to the mouth near the center of the lower surface.

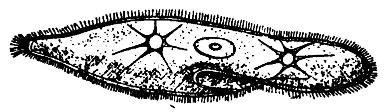


Fig. 125.—Paramæcium.

The whole body is covered with fine cilia, and sometimes a cluster of longer, coarser setæ is noticeable on the posterior extremity. In the writer's locality this cluster of cilia (setæ) is present on all the specimens; he has never seen a *Paramæcium* without it.*

This Infusorium increases rapidly by dividing into two parts across the middle. Its movements are rapid.

The two stellate objects in the figure are the contractile vesicles; the central, oval body is the nucleus.

18. Euplótes (Fig. 126)

This is one of the walking Infusoria. The cilia (styles) on the flat lower surface are large and strong, and the animal uses them for swimming, or it walks about the slide or climbs among aquatic plants by resting part of its weight on their tips as if they were legs. When the creature happens to be turned on its back, these large cilia (styles) may be seen pattering irregularly against the cover-glass. They vary in number from ten to twelve.

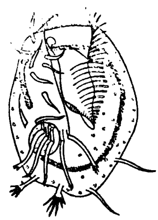


Fig. 126.—Euplótes.

* Since this was written, these two forms have been separated as two distinct species, one with the caudal tuft, the other without.

The front border has a row of finer, but still large cilia that extend down the side of the flat surface to the mouth, near the center of that part of the body. Four straight, stiff hairs project from the posterior margin, two or them often being divided into fine branches.

The back of the Infusorium has no cilia, but is a hard surface, almost like that of a shell. The animal is very active. There are several species common among *Ceratophyllum* and *Myriophyllum*. The figure (FIG. 126), shows the lower surface.

19. STYLONÝCHIA (FIG. 127)

To the beginner, the members of this genus will closely resemble *Euplótes*, as all the cilia are confined to the frontal border, to the part about the mouth, and irregularly distributed over one side of the flat lower surface, as walking organs. It can, however, easily be distinguished from *Euplotes* by its shape, as it is much more oblong. Sometimes it is long and narrow, while *Euplotes* is always more or less circular. It has no cilia on the back, which is usually hard and shell-like. The species are several, all being especially common in vegetable infusions. The figure (FIG. 127) shows the lower surface.

FIG. 127.—Stylonýchia.

20. CHÍLODON (FIG. 128)

The body is more or less oval and flattened; the lower, or flat ventral surface alone is ciliated. The front border is convex, and rather sharply pointed at one corner; the side of the body extending from this corner to the rounded posterior margin is nearly straight, while the opposite side is strongly convex. The back is smooth and bare.

From the pointed corner, a curved line of cilia extends back over the flat surface to the mouth, and, when vibrating, resembles an undulating membrane. A high power is needed to show the separate cilia.

The mouth opens into a cone-shaped bundle of fine rods visible under a high power. The ends of these rods can be

seen with a moderately low power, encircling the mouth like a row of beads.

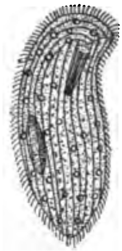


FIG. 128.—Chilodon.

The Infusorium lives upon smaller Infusoria and Diatoms, which it seizes by protruding this peculiar throat, the rods separating as the food is slowly swallowed. *Chílodon* is common in still waters.

The numerous small circles in the figure (FIG. 128), which shows the lower surface, represent the contractile vesicles.

21. LÓXODES (FIG. 129)

The body is long and narrow, the frontal border convex, with one corner rather acute. On one side, just below the pointed corner, is a concave space containing a brown, sickle-shaped body, lining the hollow which is part of the Infusorium's throat. The upper portion, or blade of the sickle, seems only to stiffen that part of the cavity; the true mouth is at the beginning of the short hollow handle.

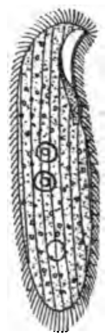


FIG. 129.—Lóxodes.

The cilia are fine, and are on the lower flat surface only. The body is flexible, often bending on itself. The Infusorium is common in some localities.

The two small circles near the middle of the figure, each surrounded by a larger ring, are the two nuclei. The single circle near the posterior end represents the contractile vesicle.

The only comprehensive English work on the Infusoria is "A Manual of the Infusoria: including a Description of all known Flagellate, Ciliate, and Tentaculiferous Protozoa, British and Foreign," by W. Saville Kent, published in London, 3 Volumes, royal 8vo.

CHAPTER VI

HÝDRA

When Hercules was going about doing those wonderful things of which we have read, it was suggested that he should turn his attention in the direction of Lake Lerna, near Argos, where a monster with a hundred heads was making itself unpleasantly active. He visited the place and interviewed the creature, but when he had cut off one of the heads, he must have been surprised to see two new ones sprout out of the bleeding surface. It was discouraging, but the hero began to have the best of the contest when he began to burn the fresh cuts with a hot iron.

The monster was the Hýdra of mythology. Science has preserved its memory by giving the name to a common and peculiar creature that inhabits our ponds and ditches.

The fresh-water *Hydra* (there is no salt-water *Hydra*), has a soft and elastic body, elongate-cylindrical in form, attached by the tip of one end to an aquatic plant or other submerged object, and with from five to ten long, slender, extensile arms arranged around a mouth at the opposite end. In color the animal is usually pale brown or green. All the species are plainly visible to the naked eye.

The bodies and tentacles are exceedingly extensile and active. The bodies can, when full-grown, be stretched out to a length of from one-eighth to one-fourth, or sometimes, one-half of an inch.

The posterior extremity is adherent to some supporting object, while the body and tentacles extend freely into the water, lengthening themselves in search for prey, and quickly shortening until the body is like a little mass of opaque brown or green jelly clinging closely to the supporting object, with the tentacles contracted into small, rounded projections or knobs

about the frontal border. These knobs may not be visible to the naked eye. When disturbed, the animals quickly assume the contracted form, and it is in this condition that the collector will usually find them at the moment when they leave the water. Collecting them is like the gathering of so many other microscopical creatures; it must be done largely by faith.

When in search of *Hydra*, the reader should remember that they are from one-eighth to one-half of an inch in length when extended, that they are both brown and green, and adhere to submerged plants and to other objects in the water; also that the brown species are more easily seen by the naked eye than the green, especially if the green *Hydra* is attached to a green leaf or plant; also that they are exceedingly extensile and contractile, and that each will probably be contracted into a little, invisible lump when taken from the pond.

They are to be found in almost any body of still, fresh water, in which there is an abundance of submerged aquatic growth to which they may cling, and that may harbor their prey. They will be more plentiful where there is a plentiful food-supply. The exact localities cannot be more explicitly pointed out.

Gently draw to the shore a mass of submerged plants, and transfer portions of them to the wide-mouthed bottle, which should be partly filled with the water.

In some favorable localities *Hydras* are so abundant that they may at once be seen studding leaves and stems, and crowding one another, but such profusion is not common. Occasionally two or three or four may be seen attached to the plant after it has been properly treated, but usually they are not visible until after this treatment, which is easily accomplished.

When *Hydra* is wanted for study, the plants should be gathered one or two or more days in advance. If the jar be placed in the window for a day or two, sometimes for only a few hours, the animals will leave the plants, gradually make their way to the lighted side, and attach themselves to the glass, where they may easily be seen, and from which they may be taken by the dipping-tube.

To do this, gently loosen the adherent posterior end with the edge of the tube, and as the little brown or green mass of contracted and terrified *Hydra* is sinking, quickly pick it up in the tube and transfer it to a deep cell.

Almost any pond, or ditch, or slow stream will contain *Hydra* if it contain aquatic plants. The rootlets of *Lemna* are often a favorite locality. These plants need only to be swept from the water by the tin dipper and transferred to the aquarium, where the animals will seek the best lighted side. They

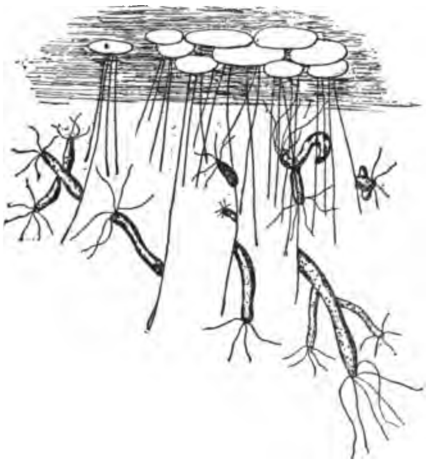


FIG. 130.—Hydras adherent to Lemna rootlets.

may be seen by looking through the glass, gently turning toward the observer, if need be, the side then toward the light, and waiting for a few moments until the body and the tentacles are extended, when the dipping-tube will easily pick them out.

In Fig. 130 several of the animals in different stages of reproduction by budding, are shown attached to the rootlets of *Lemna*. They are there slightly enlarged, although specimens almost as large as these are represented to be are not uncommon.

The body is like a narrow cylindrical bag; the hollow part of the little sack is the stomach. By means of the mouth it

communicates directly with the external water, in which the *Hydra* lives.

Around this mouth are arranged the arms or tentacles. These are themselves hollow, and communicate with the cavity of the body.

The food consists of small worms, water-fleas or other Entomostraca (Chapter X), or even of little pieces of raw beef, if the observer choose to feed them to the *Hydra*. They seize the living victim as it is swimming by, and twining a tentacle around it, draw the struggling creature to the mouth through which it is thrust into the stomach. The act of seizure takes place so rapidly that the eye can seldom follow it. The observer can usually know that the prey is caught, only by seeing it slowly approaching the oral aperture. Often, when the captured object is too large or strong for one arm to hold, several tentacles bend over and twine around it. A creature once caught rarely escapes.

The writer has amused himself, and doubtless pleased the *Hydra*, by feeding them with small larvæ or with aquatic worms. Take in the forceps a small aquatic worm by one end, and present the wriggling thing to a *Hydra's* arm. No second invitation is needed. The worm is quickly embraced. If too long to be swallowed all at once, part of it will hang out of the mouth until the other end is digested; the tentacles in the meanwhile will not cease to fish for more.

It is said that if the *Hydra* and the worm are placed together in a deep cell under the microscope, the performance may be watched through a low-power objective. The writer has never succeeded in doing this, but there is no trouble in feeding the creatures in an aquarium. They never eat any but animal food. They are always hungry.

The body and tentacles of *Hydra viridis* are roughened by little elevations or warty prominences. The brown species is not so much roughened. These protuberances contain what are called the stings, small, oval, or vase-shaped hollow bodies, with a fine thread coiled in the interior, and four minute spines near the summit. When the *Hydra* is irritated by the pressure

of the cover-glass these stings are thrown out violently, and the long stiff thread can be well seen. When in the animal's body they cannot be so easily examined. One is shown much magnified in FIG. 131. They are often found on the slide when no *Hydra* is to be seen. They are sometimes noticeable sticking in the body of some worm or larva that has escaped a fatal embrace. The writer has more than once found a *Chirónomus* larva (Chapter VII) in a dying condition, and ornamented by a spiral band of these stings in its skin. It had evidently had a tussle with a *Hydra* and escaped.

FIG. 131.—Hydra sting.

Hydra increases in numbers rapidly, by a process of budding. A little protuberance appears on one side of the body, enlarging and growing, and finally, while still attached to the parent, developing tentacles. It then resembles the mature animal in everything except in size. It is not unusual to see one or more still younger *Hydras* sprouting from these, before they are free from the parent.

The body of the young is hollow, and communicates with the body-cavity of the parent. It captures food like the parent. It is no uncommon sight to observe both the old and the young *Hydra* seize the same worm at the same time. In such cases the stronger wins, unless the worm breaks in the unfilial struggle, when the parts go into the one common stomach, through two separate mouths.

Two young *Hydras* may often be noticed growing from the sides of a single older one. Instances of this are shown in FIG. 130. The budded young finally separate from the parent, to lead an independent life, and soon to produce young *Hydras* from their own sides, if they have not already done so.

The creatures are hardy. They will endure much harsh treatment, and seem to thrive under it. They have been made the victims of many apparently cruel experiments, but they are probably not very sensitive to a feeling of pain. The sensation of hunger, and a sense of touch delicate enough to recognize a desirable morsel, or an obnoxious object when it

comes in contact with the tentacles, are probably the extent of their feelings.

Trembley, a Dutch naturalist who studied the *Hydra* as long ago as 1739, first called attention to the harsh treatment that they will endure and live. In a rather quaint, old-fashioned translation it is said, that, "If one of them be cut in two, the fore part, which contains the head and mouth and arms, lengthens itself, creeps, and eats on the same day. The tail part forms a head and mouth at the wounded end, and shoots forth arms more or less speedily as the heat is favorable. If the polype be cut the long way through the head, stomach, and body, each part is half a pipe, with half a head, half a mouth, and some of the arms at one of its ends. The edges of these half-pipes gradually round themselves and unite, beginning at the tail end; the half-mouth and half-stomach of each becomes complete. A polype has been cut lengthwise at seven in the morning, and in eight hours afterwards each part has devoured a worm as long as itself."

Trembley also sliced them across, and found that each piece developed a cluster of tentacles. He finally turned them inside out, and in a few days the maltreated creature swallowed food, although its old skin was now lining its stomach, and its old stomach-membrane had now become the skin. This is Trembley's account. More recent experimenters have doubted the correctness of this explanation, preferring to believe that while Trembley was absent, or a little absent-minded, the everted *Hydra* quietly turned itself right side out, and so deceived its tormentor.

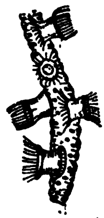


FIG. 132.—Trichodina pediculus—Parasite of Hydra.

There is a peculiar parasitic Infusorium (FIG. 132) often seen in considerable numbers gliding rapidly over the body and arms of the *Hydra*, especially of *H. viridis*. They do not seem to be objectionable guests, as the *Hydra* never appears to notice them.

It is said that they infest sick or weakly victims only, but

that is not according to the writer's experience, if the condition of the *Hydra* may be judged by appearance, activity, and appetite.

Several of these parasites are shown on a portion of a tentacle in FIG. 132. Each is shaped like a short dice-box, with a circle of fine cilia at each end, but none on the rest of the body. It glides along rapidly on the end of the dice-box, running out to the tips of the tentacles, and skirting fearlessly around the edges of the mouth. It is the *Trichodína pedículus.* When fully extended it is nearly as long as it is wide. It then measures, each way, about 70 microns.

The *Hydra* also occasionally has another form of Infusorial parasite running over its skin. This is depressed and somewhat kidney-shaped in contour, and has cilia only on one surface, the lower or ventral surface. It is called *Keróna polypórum.* It is not so common as *Trichodína,* yet both parasites are sometimes seen together on the same *Hydra.*

If the observer desires to preserve the *Hydra* as a permanently mounted object for the microscope, he may be easily gratified, thanks to the late A. H. Breckenfeld, of San Francisco, who devised an admirable method that the writer has tried and can recommend.

Transfer the *Hydras* to a slip in a large drop of water, where they can be easily seen if the slide is held above white paper. When their tentacles are fully extended, "quickly move the lamp directly under the drop, with the top of the chimney about an inch beneath the slide, and hold it in that position for from three to five seconds, the exact time depending principally upon the intensity of the heat. Then quickly remove the slide and place it upon a slab of marble or of metal. When cool, pour the drop containing the zoophytes into the prepared cell on the slide which has been held in readiness; add a drop or two of a suitable preservative fluid, arrange the little animals, if necessary, by means of a needle or a camel's-hair brush (using very great care, however, as the tentacles will be destroyed by the least rough handling), cover with thin glass, and finish as in the case of any fluid mount."

The writer has not found it necessary to use two slips of glass. If a deep shellac cell that has been made for some time and is perfectly dry and hard, is used, the *Hydra* may be placed in it and there cooked and allowed to remain, as a high degree of heat is not needed. When the glass is cold, arrange the arms if necessary, add a drop of weak glycerine and water, and cement the cover-glass with shellac. The *Hydra* thus prepared can be kept indefinitely, and at any time shown to admiring friends. The author has at this writing a preparation thus made, and still in perfect condition, although it was mounted twenty-five years ago.

There are two brown species in our waters, *Hýdra fúsca* and *Hýdra vulgáris.* These the naked eye will easily separate by the comparative elongation of the extended arms or tentacles, those of *H. fúsca* being exceedingly fine and thread-like, often stretching to a length of from three to six inches. I have seen them three inches long. Those of *Hydra vulgaris* are much shorter and stouter and when fully extended, scarcely exceed in length that of the body. Of these two forms in the writer's locality, *H fúsca*, with the long tentacles, is more frequently seen than *H. vulgaris.* The green species, *H. viridis,* is common and abundant.

The following short synopsis may help in their identification.

Species of Hydra

1. Body brown (*a*).
1. Body green. *H. vĭridis.*
   - *a.* Extended tentacles not longer than the extended body. *H. vulgáris.*
   - *a.* Extended tentacles many times longer than the extended body. *H. fúsca.*

CHAPTER VII

AQUATIC WORMS, CHÆTÓNOTUS, AND CHIRÓNOMUS LARVA

THE collector of microscopical objects from the ponds and slow streams is doubtless familiar with the appearance of the bristle-bearing worms (FIG. 153), on account of their general resemblance to those long-suffering creatures which he, in his youth, impaled on a hook, and with them sought the nearest water. The extensive bristles of the aquatic worms are an addition which greatly lessen their resemblance to the common earth-worm, and their transparency is another characteristic that may temporarily mislead the observer, but their elongated bodies and general worm-like aspect tell the story.

Aquatic worms merit all the attention that any microscopist can give them. They form a field that has been but slightly cultivated in this country, yet it is an important one in which discoveries may be made.

These worms abound in all the ponds and shallow bodies of water in the land, living even in mountain streams, if these are not too rapid.

They usually occur in the surface ooze of any shallow pond; in the soft and decaying matters on the surface of old, water-soaked sticks and logs; on the surface of last year's dead leaves in the ditch, and among the freshly growing *Lemna* and Algæ that float in the water almost everywhere.

They are usually so transparent that their internal organs may be easily seen. The creatures are especially interesting on account of this peculiarity, as their internal anatomy is remarkable in many particulars. Their method of reproduction by transverse fission is another item in their favor, as frequently a worm is met with that is plainly more than a single creature, yet less than a double one.

In the writer's locality, there is one object that, from about the middle of August, begins to be a fruitful source of supply for these interesting animals. This is the dead and decaying clusters of the beautiful Polyzoan, *Pectinatélla magnífica* (Chapter IX). These colonies of microscopic animals are so common in my neighborhood that it is an ordinary occurrence to find them in floating clusters as big as one's head. While paddling about in a boat on a small lake, I have, in a single hour, seen four floating colonies of such size. They were all dead and in process of decay, but as sources of supply for aquatic worms they could not be excelled; the softening mucus was literally alive with the worms, and the naked eye could see them crawling about the soft mass, and wriggling over the hand that had lifted the colony from the water. They seemed to feed greedily on the mucus which surrounds the bodies of the Polyzoans, as well as on the decaying bodies themselves. Those microscopists that have these colonies in any abundance in their ponds, should not neglect them in midsummer and early autumn, if aquatic worms are desired.

The worm's organs of locomotion may be used for purposes of identification, when the microscopist does not care to be strictly scientific, nor to classify the creatures as the advanced naturalist would classify them. These organs are the clusters of bristles on the sides near the back, and the groups of foot-spines on the lower or ventral surface.

In addition to the bristles which most members of this class possess, there are usually two or more rows of long, curved spines (FIG. 154), on the ventral or lower surface. These can be protruded or withdrawn into the body at the possessor's will. When protruded they are used to assist the worm to crawl. They are therefore called the podal spines or foot-spines. They may not be noticed when retracted unless they are specially searched for, but having observed them, and the bristles in a row on each side above them, the student need have no trouble in deciding where to class their owner.

The dorsal bristles are colorless, as are the foot-spines,

but they are flexible, and appear to be used more as feelers or sensory organs than as locomotor appendages.

The true motor organs are the ventral, podal spines. These are gracefully curved, like the long, old-fashioned ſ of our grandfathers' days; they are stout and rigid; they usually have an ovate or sub-spherical enlargement somewhere along their length; their free or external ends are usually forked, and they are arranged in groups which together form two or more parallel rows along the lower aspect of the body. These podal spines are not rarely seen in the débris that comes to the pond-hunter's slide, the worm having died and left these imperishable objects to perplex the observer.

Most of the worms are, under favorable conditions, visible to the naked eye as whitish threads undulating through the water, or clinging to the sides of the microscopical aquarium.

Some, *Nâis* for instance, will cement together the fronds and the rootlets of *Lemna*, with other vegetal bits and cantles, into a tube that they singly inhabit and drag about with them. I have been amused by watching *Nâis* struggling to draw these light dwellings down the side of the vessel, the worm's mouth clinging by suction to the glass, and the contracting body striving to drag the tube; but as the domicile is specifically lighter than the water, the chances are that the upward levitation will be too great for the suction power, and the struggling *Nâis* will suddenly and involuntarily rush backward to the surface.

I have more than once seen such a tube, or case, inhabited and dragged about by the builder that had formed it exclusively of the winter eggs or statoblasts (Chapter IX), chiefly of *Plumatella*, with a few from *Pectinatella* scattered over the surface. Adhering to it, as uninvited guests, were numerous *Stentors* and other Infusoria; one of the *Stentors* was especially interesting, as it is a species rare in my locality, and one that I had not previously seen.

Dêro is in the habit of burying itself head first in the mud, leaving only the tip of the funnel-shaped posterior extremity protruding into the water, where it waves backward and for-

ward, and by means of the anal cilia, drives an oxygenating current into the intestine, through the surface of which the blood is aerated.

Tubifex has a somewhat similar habit; but it builds a tall tube of mud from which it protrudes its posterior extremity, and into which, at the slightest disturbance, it retreats with a rapidity that is amazing at one's first experience with the worm.

Another common group of aquatic worms is not quite so easily observed. These have flattened, usually semi-transparent bodies, with the entire surface densely clothed by fine cilia. Probably on account of the stir and disturbance which the cilia make in the water, naturalists have classed such worms together under the name of the *Turbellária,* a word meaning a stir or bustle.

Their motions are rapid and apparently without effort. They glide smoothly and swiftly over submerged objects, or not rarely swim back downward on the surface of the water. Some of these *Turbellárians* are shown in FIG. 145.

This group may be recognized by the presence of the cuticular cilia, which a low-power will usually reveal, or it at least will exhibit the currents that they produce.

All the *Turbellarians* have an extensive digestive system, but the members of one division have no anal aperture; the excrementitious matters are expelled through the mouth. In another section are grouped those with the intestine branched and arborescent, while still others have a straight, undivided intestine.

There is yet another group of common aquatic worms, but to recognize them will give even the beginner little trouble. They have a perfectly transparent, usually smooth, thread-like body, apparently truncate in front, and prolonged posteriorly in a sharpened, point-like tail. They have no bristles nor cilia, and they rather closely resemble a microscopic eel; the scientific name, *Anguillula,* means a little eel. These are closely allied to the well-known vinegar eels, and to the equally common paste-worms.

Many members of all these classes are found in the super-

ficial sediment of shallow ponds; in the crevices of wet and water-soaked logs; under submerged stones; among the leaflets of *Myriophyllum*, *Sphagnum* and other water-plants.

Sphagnum seems to be a favorite place for several kinds. The writer has obtained members of five genera, *Náis*, *Pristína*, *Dêro*, *Chætogáster*, and *Æolosóma*, by placing a little piece of the moss in a watch-glass with a small quantity of water, and gently tearing away the leaves with needles, when the concealed worms hurried out and were readily captured with the dipping-tube. If the watch-crystal stands on black paper this work is facilitated, as the translucent worms then appear to the naked eye as minute, writhing, silvery threads.

In this chapter the reader will also find descriptions of two common microscopic aquatic animals, one of which is certainly not a worm, the proper position of the other being rather doubtful. They are *Chætónotus* and the *Chirónomus* larva (FIG. 133, 134). Each has a somewhat worm-like body. They are here referred to for the convenience of both reader and writer, as the observer will be sure, at first, to mistake *Chironomus* larva for a worm.

The bodies of all the aquatic worms are soft and easily injured. It is best, in studying them, to use a cell shallow enough somewhat to restrain their movements, when the cover glass is added, but deep enough to avoid undue pressure, or they will rapidly go to pieces.

The following Key will assist the reader in determining to which class his worm, or worm-like creature, may belong, and will lead to the names of the groups under which some of their generic titles may be found:

Key to Classes and Genera of Aquatic Worms

1. Body with four leg-like appendages bearing hooked bristles; eyes distinct; head large, brownish-red. *Chirónomus larva, I.*
2. Body without leg-like appendages (*a*).
   a. Tail forked; mouth small, circular, on the front part of the lower or ventral flat surface; back convex, usually

bearing spines, prickles, tubercles, or scales. *Chætónotus*, *II.*

a. Tail not forked (*b*).

b. Posterior extremity often bearing finger-like appendages, never long, coarse bristles (*c*).

b. Posterior extremity rounded, often bearing long bristles; animal free-swimming, movements swift. *Dasydýtes*, III.

c. Body entirely and finely ciliated, usually flattened; not divided into distinct segments or rings. *Turbellária*, IV.

c. Body smooth or transversely striate; without cilia, bristles or spines; worm-like; posterior extremity pointed. *Anguíllula*, V.

c. Body elongated; divided into segments or rings; with bristles, podal spines or both. *Oligochæta*, VI.

I. Chirónomus larva (Fig. 133)

Chirónomus larva has a worm-like, more or less segmented, colorless body, eight or nine times as long as wide, a large head, with the mouth parts usually distinctly apparent. The four, short, rudimentary leg-like appendages are in pairs on each end of the long body, with the brownish hooks, or strong, curved bristles on their extremities more or less retractile. In some forms two clusters of long bristles spring from the upper surface, near the posterior border of the animal.

The perfect insect into which this larva will develop, is a two-winged fly resembling the mosquito. These are often seen in great numbers above the ponds and marshes. The species are numerous, but they have not been studied by American entomologists.

The eggs are common on sticks, floating chips, or other objects in the water, or even in freely floating masses. They are apparently deposited, at least, they are found in an immense amount of jelly, huge in bulk when compared with the size of the insect, the eggs appearing to the naked eye as distinct but minute, often brownish, specks, frequently arranged in beautifully regular rows.

It is always interesting as well as important for the collector to take all the little jelly-like egg masses that he may find attached to submerged objects. If placed in a watch-glass or in an "individual butter-dish," and the water kept fresh and pure, they will usually hatch, and thus give the observer valuable information often not otherwise obtainable. *Chirónomus* eggs can hardly be described so that the reader shall recognize them at first glance, but if once hatched out at home, they will afterward always be recognizable. The first little mass of jelly experimented with may prove to be snails' eggs, but they will be none the less interesting. They may also prove to be the eggs of water-mites (Chapter XI). The observer will, of course, not mistake the green jelly-globules of *Chætóphora,* one of the Algæ, for insect eggs.

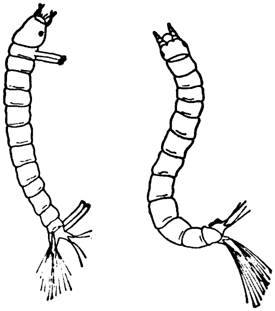


FIG. 133.—Chirónomus larvæ, greatly enlarged.

II. CHÆTÓNOTUS (FIG. 134)

There are several species of these lithe and graceful little creatures in our fresh waters. They so closely resemble one another in external form, that they can be distinguished only by the cuticular appendages, or by the coat-of-mail by which most of them are protected.

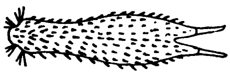


FIG. 134.—Chætónotus lárus.

They are readily to be found by fishing for them with a dipper, as recommended for Rhizopods, since they are fond of gliding over the soft ooze at the bottom of shallow ponds. If the collector will also sweep his dipper under the lily leaves and among the submerged stems of other aquatic plants, he will not be disappointed.

The animal consists of a free-swimming, flexible, and elongated body, the anterior extremity usually enlarged to

form what may be called the head, a slight constriction behind this part constituting the neck.

The broadened central portion of the body is formed with convex lateral borders, and a more or less strongly arched back or dorsum. This region is variously appendaged with spines or with scales, and suddenly narrows to produce the posterior extremity, which is forked, and bears two conspicuous, but short, tail-like prolongations.

The lower or ventral surface is a flat and nearly level plane, extending along the entire length of the body. It bears one longitudinal band of cilia near each lateral border, seldom more.

The head is usually somewhat triangular, and is formed of three or of five rounded lobes. It bears two tufts of vibratile hairs on each side.

The mouth is on the ventral surface of the head. Under a moderate amplification it seems to be a circular opening, but with an objective of high power it will be found to be beaded and somewhat complicated in structure, as shown in FIG. 135.

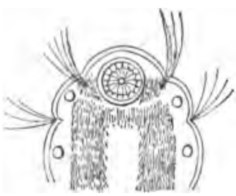


FIG. 135.—Head of Chætonotus, ventral aspect.

The whole upper surface of the body is, in the different species, covered with rounded papillæ, scales, spines, or prickles, or with both scales and spines at the same time. In the latter kinds, the scales cover the back and sides, and the spines spring from these appendages, and arch back toward the forked tail. In all cases, these little scales are imbricated, like the shingles on a roof, only they have the peculiar habit of overlapping in what seems to be the wrong way, because their free margin, or that region which represents their free margin, points toward the animal's head, or in a direction exactly opposite to that of the scales of a fish. They are usually small, and require high powers to show them properly.

The two caudal prolongations are movable and flexible. Their chief use seems to be to anchor the animal to the glass slide or cover, or to some object in the water where they cling

with their tips, and are apparently assisted by a secretion that is supposed to exude from them, this sticky fluid passing from two ovate glands usually visible in the upper or anterior part of each.

The mouth opens into a strongly muscular œsophagus, which itself opens into the intestine, a tapering, tubular passage, lined with nucleated cells and passing in almost a straight course along the median line, to terminate between the two caudal prolongations.

If the observer can get the animal in such a position that he can focus down on the front of the head, he will see that the cavity of the œsophagus is triangular. It is not difficult to do this, since the little creatures are exceedingly restless; they are continually turning and writhing about, and lifting the head in various directions.

This feature in its structure can often be seen in the animal while still in the egg, for even there, when almost ready to escape it is restless. The eggs are not rarely found on the slide, with the young *Chætónotus* doubled up and squirming within.

The eggs by which *Chætónotus* is reproduced are formed in an ovary difficult to see, unless occupied by an egg. It is placed in the median line of the body immediately above the intestine. Usually only one egg is formed at a time, but it is not rare to see two or more in various stages of ovarian development. Upon the absence or presence of an egg in the ovary depends, to a great extent, the degree of convexity of the back. The eggs are dropped anywhere in the water, and left to the care of Nature.

The food consists of the minute particles of decayed animal and vegetable matter, so abundant in the soft surface of the mud at the bottom of our shallow ponds. These particles are taken in with a peculiar and sudden snapping movement of the cavity of the œsophagus, easy to see but difficult to describe. Diatoms are rarely swallowed.

So far as their classification is concerned, these attractive little animals have given naturalists a good deal of trouble. Some have said that they belong with the Rotífera; others

have placed them among the Infusoria; others have called them low worms, putting them among the Turbellária; and still others think, and they are doubtless correct, that *Chætónotus* should stand in a group by itself, among the worms, and not far from the Rotífera, the group to be named the Gastrótricha.

They are all rapid swimmers. On that account they are rather difficult to study, but by following one for a little while, it will usually settle down and begin to seek food. That is then the observer's opportunity, unless he desires to kill the specimen, and study it after death, a procedure that is seldom satisfactory.

The following Key leads to some of our common forms:

Key to Chætónotus and to its Allies

§ Posterior extremity forked (*A*).

§ Posterior extremity not forked, but bearing several long, coarse bristles. *Dasydýtes*, 1.

A. Upper surface without spines, prickles or scales, (*a*).

A. Upper surface having scales, spines, spinous scales or prickles, (*b*).

a. Back smooth and naked, or transversely furrowed, or bearing small, hemispherical elevations. *Icthýdium*, 2.

b. Caudal prolongations much shorter than the body; not segmented nor ringed; dorsal scales, when present, rounded. *Chætónotus*, 3.

b. Caudal prolongations long, ringed or segmented, often curved; scales rhomboid or diamond-shaped. *Lepidodérma*, 4.

III. (1). DASYDÝTES SÁLTITANS (FIG. 136)

In contour this lively creature remotely resembles *Chætónotus* (FIG. 134), but differs in a shorter, more chubby body, in the presence of a more distinctly formed neck, and especially in the absence of a furcate caudal extremity.

The body is colorless and transparent. Its internal structure is not widely different from that of *Chætónotus*, but in general appearance the animal lacks the graceful form and the

attractive movements of *Chætônotus*. The posterior extremity is simply rounded or truncately convex. The animal's movements are much less smoothly gliding and facile. The habitat of both genera is the same, being chiefly near the bottom of shallow ponds.

The head is distinctly three-lobed. The frontal lobe is the smallest. It bears on its anterior border a colorless, apparently chitinous plate or cephalic shield. Both surfaces of the head are ciliated. These cilia are long and fine, and are arranged in two distinct, transversely encircling series, the posterior row projecting and vibrating anteriorly, while the anterior series projects and vibrates posteriorly.

The neck is about as long as the head, sometimes rather longer. It is movable and exceedingly flexible, the *Dasydŷtes* continually bending it from side to side in search of food, or upward and downward.

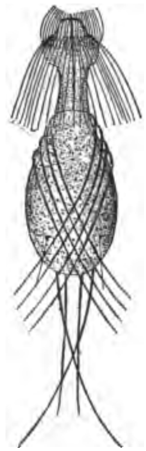


FIG. 136.—Dasydytes saltitans.

The animal has the habit of turning occasional somersaults, accomplishing this feat by flexing the neck under the ventral surface and throwing the body over forward.

From each side of what may perhaps be called the shoulders arise from four to six large, coarse bristles, each as long as the entire body. These sets of bristles cross each other obliquely above the back, and project beyond the rounded posterior extremity. Without these the dorsal surface would be naked, except for the presence of two, fine, almost vertical tactile hairs, each of which arises from a small papilla near each postero-lateral border.

The ventral surface is not easily seen, as the animal usually keeps it obstinately directed downward. But the ventral cilia are essentially similar to those of *Chætonotus*, and are arranged in two lateral, longitudinal bands.

Near the center of this aspect originate four strong coarse bristles, or setæ, two long and much exceeding in length that of the whole body, and two shorter, the four projecting beyond the posterior border. These are springing setæ by which the *Dasydytes* makes those surprising leaps, which suggested its specific name of *saltitans*, or leaping, the animal often jumping, and always unexpectedly, to a distance sometimes exceeding twice its length. This seems to be great, but in reality is small, as the length of the body is only about $\frac{1}{300}$ inch, or about 84 microns. When swimming its movements are more rapid than those of *Chætonotus*.

The mouth is nearly apical. The œsophagus has a snapping movement similar to that visible in *Chætonotus*, although the food is usually engulfed by suction, living and comparatively large Infusoria, being taken, as well as organic particles.

Dasydýtes sáltitans does not seem to be common. It was originally discovered near Trenton, N. J., where it is rather rare, and has been found near West Point, N. Y. It has not been reported elsewhere.

2. Icthýdium

1. This resembles a *Chætónotus* with a smooth, naked back, all scales, spines and prickles being absent. The spines and other dorsal appendages are represented by two hairs standing almost vertically on the neck, and two on the posterior part of the back. These are usually seen with difficulty, but they are present on all the species, even on the scaly and the spinous *Chætónotus*. The egg of this species is also smooth. In other particulars it resembles *Chætónotus*. This is *Icthýdium podúra*.
2. The characteristic of this form is the deep transverse furrows conspicuously developed on the back and sides. The body is transparent, and unusually soft and flexible. The posterior region, between the arch of the back and the caudal furcation, is narrowed, and much longer than in other species. The œsophagus is short, being not more than one-sixth of the length of the body. *Icthýdium sulcátus*.

3. A similar animal, but with the dorsal and lateral surfaces closely covered with small hemispherical elevations arranged in oblique lines, and giving the creature a peculiarly neat and attractive appearance. *Icthýdium concínnus.*

3. Chætónotus (Figs. 134, 135)

"Bristle-back," the literal meaning of the word, seems to be a misnomer when those forms are concerned in which the bristles are replaced by scales, but the structure is such that the only resting place for the creatures is in the genus *Chætónotus.* The following Key leads to a few of the common species:

Key to Species of Chætonotus

A. Upper surface bearing scales only; scales rounded, *loricátus*, 1.

A. Upper surface bearing spines or prickles only (*a*).

A. Upper surface bearing both spines and scales (*b*).

A. Upper surface bearing posterior spines and anterior prickles (*c*).

a. Spines long, covering the entire upper surface; mouth beaded, *máximus*, 2.

a. Spines short, covering the entire upper surface; mouth not beaded, *lárus*, 3.

a. Spines not covering the entire upper surface (*d*).

b. Back with a subcentral, transverse hedge of large spines; scales double, *acanthódes*, 4.

b. Back without distinct spinous hedge; scales not double, *spínifer*, 5.

c. Spines in four transverse rows, five spines in each, *acanthóphorus*, 6.

c. Spines in transverse rows, less than five spines in each, *enórmis*, 7.

d. Spines eight, in two longitudinal rows of three each, with one anterior and one posterior central spine, *octonárius*, 8.

d. Spines in two transverse rows, not projecting beyond the ends of the caudal prolongations, *spinósulus*, 9.

d. Spines in two transverse, highly arching rows, the posterior longest and projecting beyond the ends of the caudal prolongations, *longispinósus*, 10.

1. Chætónotus loricátus (Fig. 137)

The scales on the back and sides are arranged in imbricated rows, the convex free margins directed forward. Although so completely covered, the body is flexible, the scales freely sliding over one another when the animal bends or curves to one side. The mouth is obliquely placed, as may be seen when the *Chætónotus* is viewed in profile, and its internal margin is strongly beaded. The eggs are armed by hollow papillæ, or by short hollow spines, whose summits are bifid or emarginate.

Fig. 137.—Chætónotus loricátus.

2. Chætónotus máximus

The back and sides are covered with spines, which are often rather longer on the posterior region than elsewhere. These are arranged in longitudinal parallel rows, yet they often seem to be irregularly scattered, so that the animal presents an untidy, disheveled, and disreputable appearance. The spines are minutely forked near the free ends, but the branching is uneven and is easily overlooked; one branch is very small, often scarcely more than a minute linear projection.

The ventral cilia are in two longitudinal lateral bands; the space between the bands is clothed with short, recurved hairs. Two or more long fine bristles project from the same part beyond the posterior border, between the two caudal branches.

3. Chætónotus lárus (Fig. 134)

The whole upper surface is clothed with short, conical spines in longitudinal rows; these appendages are recurved but not branched. They are often largest posteriorly. The mouth is not beaded. The ventral cilia are in two broad longitudinal

bands near the lateral margins; the intervening space often bears two additional parallel lines of cilia. These may be absent from some specimens. These cilia, as in all the species, subserve locomotion. The egg is smooth, or hispid with short hairs.

4. Chætónotus acanthódes (Fig. 138)

The upper surface of this form is wondrously well protected. It possesses both spines and scales. The scales are imbricated, and their somewhat pointed, free margins are directed forward, each one bearing a small supplementary scale or scale-like thickening on its posterior part, from which springs a recurved, unequally furcate spine. Near the body-center the dorsal surface is traversed by a series of large, stout spines rising obliquely upward and backward, and forming a kind of spinous hedge, the surface behind these appendages bearing a few small conical thorns, or none. The body-margins are armed by short spines.

Fig. 138.—Chætónotus acanthodes.

The central space on the ventral aspect between the two longitudinal, lateral bands of cilia is beset with short, fine, recurved prickles, and five or more long bristles project from the same surface beyond the border of the posterior bifurcation. On each side of the body, near the posterior extremity, are two large recurved spines. The animal is usually found in wet Sphagnum.

5. Chætónotus spínifer (Fig. 139)

Among *Riccia* and *Lemna* in shallow ponds this well-armored form is not rare. From each scale arises a stout, recurved, unequally and minutely furcate spine, whose base is enlarged and thickened (Fig. 139). These spines commonly originate not from the center of the scale, but near the posterior part, and between the margins of those laterally contiguous. The spines are largest and stoutest on the back

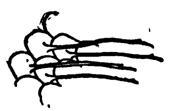


Fig. 139.—Chætónotus spinifer; spines and scales.

proper, decreasing gradually over the neck and head, and rapidly over the posterior parts. Across the dorsal surface immediately in front of the caudal bifurcation extends a supplementary series of four thorns, longer and stouter than those on any other part of the body.

The posterior region of the space between the longitudinal ventral bands of cilia bears five bristles, arranged to form a long triangle, the apex pointing forward.

The eggs vary considerably in external ornamentation, showing three patterns. In one, the ends and one side bear low, stout, hollow processes, whose apices are truncate, and four-parted or five-parted when viewed from above. In another, the appendages are long, hollow, conical spines, whose distal ends are trifid or quadrifid; the branches in profile appear very fine and delicate, but when viewed from above they are seen to taper to the ends, where each terminates in a widely spreading furcation. In the third form, one side and both ends are covered by an irregular network of raised lines, the meshes being four-angled or five-angled, while the opposite side is rugose with fine, minutely sinuous lines.

FIG. 140.—Chætónotus acanthóphorus.

6. CHÆTÓNOTUS ACANTHÓPHORUS (FIG. 140).

The superior surface of the head and neck, and the lateral body-margins, are clothed with recurved prickles or short spines, while the dorsal region proper bears four rows of long thorns, each row arched towards the head, and each formed of five unequally furcate spines, with an additional one on each side near the posterior extremity. The spines rise from an enlarged base, so that the animal is almost completely clothed in an armor composed of these basal enlargements.

7. CHÆTÓNOTUS ENÓRMIS (FIG. 141)

The upper and lateral surfaces of the head and neck are clothed with short, recurved prickles; these also extend along

the ventro-lateral margins. The central and posterior parts of the back bear thirteen posteriorly directed, but only slightly curved spines, arranged in transverse rows, with three in the first row, four in the next following, two widely separated in the third, three in the fourth, while the fifth series consists of a single centrally located one.

On each side near the posterior margin are two long, conspicuous, and recurved thorns, apparently belonging to the series of small spines that fringe the lateral body-margins.

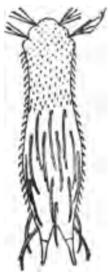


FIG. 141.—Chætónotus enórmis.

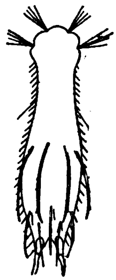


FIG. 142.—Chætónotus spinósulus.

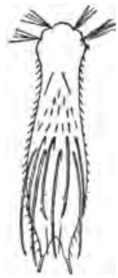


FIG. 143.—Chætónotus longispinósus.

8. CHÆTÓNOTUS OCTONÁRIUS

This is a small, active form, readily recognizable by the arrangement of the recurved dorsal spines. These are unequally branched, and placed in two lateral longitudinal rows of three spines each, with one anterior and one posterior central thorn. It seems to be the least common of the species.

9. CHÆTÓNOTUS SPINÓSULUS (FIG. 142)

The back usually bears seven unequally furcate spines in two transverse rows, four spines in the anterior series, three in the posterior. Occasionally the lateral thorns in the posterior row are suppressed, and in some individuals the front series contains but three.

The lateral body-margins are bordered by short, conical setæ. These are constant in all the specimens thus far ob-

served. The rest of the upper surface is without appendages of any kind, except the four tactile vertical bristles present in all species. The egg is hispid with short hairs.

10. Chætónotus longispinósus (Fig. 143)

The spines vary from four to eight, the latter being the usual complement. They are nearly one-half the length of the body, and curve upward and backward in a wide arch from the center of the back.

In front of the anterior row the surface is setose with stiff, recurved bristles, and the body-margins are armed by coarse, rigid setæ.

The dorsal spines are always in two transverse rows, but the number varies from four in each to three in one and five in the other. They are unequally furcate.

4. Lepidodérma rhomboídes (Fig. 144)

This is easily recognizable by the peculiar head, the minute rhombic scales covering the back and sides, and by the remarkably long and jointed caudal branches, each of the latter forming from one-third to one-fourth of the entire length of the body. The animal is the largest of the group yet discovered, measuring $\frac{1}{80}$ inch or about 290 microns in length.

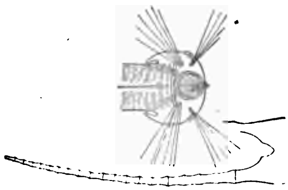


Fig. 144.—Lepidodérma rhomboídes.

The caudal branches are composed of about twenty sections or joints, each of which is slightly constricted.

The head is broadly rounded (Fig. 144), and formed of three lobes, one frontal and two lateral, the former terminating on each side in a single, acuminate, hook-like process, habitually in close apposition with the anterior region of the lateral lobes, of which the posterior extremities also terminate each in a single hook-like continuation, rather more conspicuous than those at the front.

The mouth is beaded, and has immediately behind it, on the

ventral surface a deep, narrow, transverse, and slit-like depression, rather less than one-half as long as the diameter of that part of the head. This is a problematical feature (Fig. 144).

The back and sides are completely clothed by minute, imbricated, rhombic scales, their front, pointed margins directed toward the head. They are not more than $\frac{1}{5000}$ inch or 5 microns in length, but when examined with a high power (one thousand diameters) they present a beautiful appearance. The lateral margins of each scale then seem to be thickened, and the posterior border appears to bear a minute supplementary scale in the form of a triangle.

The margins of the scales are sometimes convex. The owner of these may be another species, or only a variety. This form is so uncommon that the question has not been answered.

Although the observer may not be able distinctly to see these scales, the long, characteristic caudal branches, with their concave joints, and the sulcation behind the mouth, will be sufficient to identify the specimen. The animal is nowhere common or abundant.

IV. TURBELLÁRIA

The ciliated or *Turbellárian* worms seem to prefer the bottom of shallow ponds, probably because the food supply there is better and more easily obtained. They are soft and flexible, and some are slightly changeable in shape, having the power to lengthen themselves, to extend the posterior border into a short projection, or to narrow the front into an apology for a head. Some, however, have the anterior region naturally prolonged into a short snout. They are usually brownish and almost opaque, the opacity being increased by the large amount of food commonly present in the stomach. Three not uncommon forms are shown in Fig. 145.

The cilia clothing the entire surface are visible only under a high power. The effect of their motion, however, may be seen with the one-inch objective, as they produce currents in the water that sweep away small objects with some rapidity.

Two or more small, black or reddish eye-spots are often present near the front border, and, in some of these worms, may be rather complicated in structure; such have a covering that may not inappropriately be called a cornea, a refracting body corresponding to a crystalline lens, pigmentary or coloring matter, and a nerve.

The location of the mouth varies widely in the different families. It may be at or near the front border, at some point nearer the center of the ventral surface of the body, or even close to the posterior margin. It is usually large and expansile, and is often followed by a wide muscular organ called the

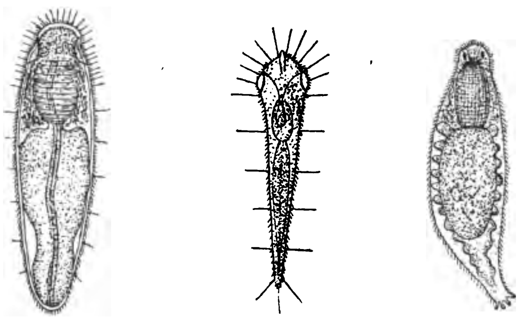


FIG. 145.—Three Turbellárian worms.

pharynx, which some of the worms can protrude, and with it snap up their living prey. The lining of the pharynx may be finely ciliated.

The stomach occupies the largest portion of the body, usually extending from the pharynx to the posterior border of the animal. In some it is simply a great sack, receiving all that the mouth and pharynx turn into it; in others it divides into many branches whose terminations may be seen near both sides of the body. The stomach seldom has a posterior opening; as a rule, there is no intestine.

After the nutriment has been digested and absorbed from the food, the insoluble remains must be ejected through the mouth. It is no unusual sight to see one of these ciliated worms

vomit up a mass of indigestible and empty Rhizopod shells, Rotifer carapaces, together with many unrecognizable particles and fragments.

The Turbellarians seem to prefer animal food, usually selecting Rhizopods, Rotifers and *Chætônotus*, but they are as fond of Infusoria, which must be as nourishing and much more easily digestible. The writer has more than once lost an interesting specimen of Infusorium because one of these Turbellarian worms had been included under the cover-glass: there were a worm and an Infusorium; a pause; a single snap, and only the worm remained. These worms are ferocious and voracious. They are the pirates of the microscopical aquarium. They might be commended if they would capture the snails, but they never do.

Propagation takes place in two ways: by eggs and by transverse fission; that is, one worm divides across the middle and so makes two, each of these in time again dividing. And often before the division has been entirely accomplished, both halves are also partly divided, so that the single body seems to be formed of several incomplete worms.

The eggs of the commonest species are brownish egg-shaped bodies, dropped anywhere in the mud or the water, or they may have a stem which attaches them to submerged objects, from which they are easily broken. The last-mentioned kind of eggs may be readily recognized, being formed of a yellowish-brown, translucent, chitinous membrane, egg-shaped, and with the stem almost equalling its own length. If the observer be fortunate, he may see the worm escape by pushing off the top of the egg that falls away like a round cover, leaving an empty case shaped like a deep cup. These empty vases are often found at the bottom of long-standing collections of plants in the microscopical aquarium.

The Turbellarian worms are common, but the observer can scarcely hope to learn even the generic name of those that he may find. He will be safe, however, if he refers to them all as Turbellarians, or Turbellarian worms. The subject has not been studied extensively by American naturalists, and there is,

consequently, nothing in the language to which the observer can be referred for help.

The worms are often visible to the naked eye as minute, whitish or flesh-colored floating bodies, or like small bits of white thread in appearance. There are two forms frequently met with that are huge, when compared with most of the ciliated creatures, and need no microscope to identify them. Both are found on the lower surface of submerged stones or sticks, or gliding over the sides of the collecting-bottle.

The body of one of these common Turbellarians may be about half an inch in length, and nearly five times as long as broad. It is opaque and almost black.

Near the anterior border are two black eyes, made conspicuous by the presence of an oblong white space in front of each.

The mouth is near the center of the body, and opens on the lower or ventral surface.

The worm glides smoothly and rather rapidly over a submerged surface. Naturalists have named it *Planária tórva.*

These Planarian worms are of no special interest to the beginner in the study of microscopic pond life, except that they may be collected in such numbers as to be a nuisance in the aquarium, from which they should be picked out, or dying, they will become even more of a pest than at first.

The second form referred to somewhat resembles *Planária tórva,* but is usually smaller, and has the anterior, or head end, more nearly triangular. It is similar in its movements and in the presence of two black eyes near the front border, each at the inner margin of a white space, thus giving the worm a cross-eyed appearance.

The body is nearly white, with a dark line passing lengthwise through the center, and giving off on both sides many short branches, that are themselves often branched, these dark lines on the white body giving the creature a rather pleasing appearance. They are not for ornament, however, but are the branches of the stomach indistinctly seen through the wall of the body.

The mouth is near the center of the lower surface.

The worm may measure half an inch in length. It has been named *Dendrocœlum lácteum.*

The writer has had this worm so plentiful in his microscopical aquarium, that they gathered on the surface in a layer so thick that it was necessary to skim them off with a strip of stiff paper used as a spoon.

The entire surface of both these common Turbellarians or Planarians is finely and closely ciliated.

The color of the body will at once inform the observer which one he has captured, as they are not microscopic in size.

V. ANGUÍLLULA (Fig. 146)

The body is thread-like, perfectly transparent, colorless, about fifteen times as long as broad, and rather widest in the middle, whence it slightly tapers toward both ends.

Fig. 146.—Anguillula.

The frontal border is rounded, but with a low power appears as if truncated. The circular mouth is at the center of this end, and leads into an oblong pharynx or throat.

The tail is usually long and sharply pointed.

The worm's movements are generally slow and deliberate, but occasionally it has a lively spell, thrashing about greatly to the detriment of other objects on the slide, and making itself a nuisance.

It is reproduced by eggs, one or more often being visible within the transparent body.

Anguillulæ are common in wet moss, among the leaflets of aquatic plants, and in the ooze of the ponds.

The well-known "vinegar-eel" is an *Anguíllula* (*Anguillula acéti*); and the paste-worm (*A. glútinis*) belongs to the same genus. Some naturalists regard these as the same species.

A somewhat rare *Anguillula* has the body transversely and rather coarsely striated by deep and conspicuous but narrow furrows that give the worm a beautiful appearance.

Eggs of the *Anguillula,* often with the young worm moving within, are frequently discovered on the slide.

VI. OLIGOCHÆTA

The fresh-water, bristle-bearing worms, whose bodies are never ciliated, show more or less distinctly that they are formed of segments or rings.

Each segment usually has on both sides, near the back, one or more long, fine, hair-like bristles extending outward into the water, and together forming a series along each side of the body.

On the lower surface are two or more rows of stouter, inflexible, gracefully curved spines, the rows formed of clusters of two or more. The free end of each spine is usually divided by a deep notch, so that it appears like a double hook. The parts are unequal in size and in degree of curvature.

These spines are used to assist in the worm's movements and are therefore called podal spines or foot-spines. They can be protruded from the body, or partly withdrawn into it, at the animal's will. The long bristles are used as an assistance in swimming.

On some of these worms both bristles and podal spines are present; from others one or the other set of organs may be absent.

The podal spines, which with but few exceptions are present, are each gracefully curved like a long italic *S*, their shape resembling the line which artists have called the "line of beauty." The free end, the one projecting into the water, is forked in a way already described, and shown in Fig. 154. The body or shaft has, at some point of its length, a globular enlargement or shoulder, below which the spine is often much narrowed. These organs are used by being protruded, and forced against the surface over which the worm is traveling. They are arranged in a row on each side of the ventral surface, each row being composed of many clusters, and each cluster of from two to ten spines. The worm can protrude several clusters at once, or two on the opposite sides of the same segment or body-ring, but it seems unable to extend them any more irregularly.

The bristles are exceedingly flexible. They are arranged

in two rows on the sides, near the upper surface, one series on each side. They are usually much longer than the width of the body, and may be arranged with several, or with only one, on each lateral margin of the segment. They are sometimes accompanied by a straight spine much shorter than the bristle, and projecting beside it. The free ends of these rudimentary spines are occasionally finely forked. The bristles are absent from some genera.

The aquatic worms are usually visible to the naked eye as fine, whitish or yellowish threads, sometimes an inch or more in length when extended. They are found abundantly among aquatic plants, and in the mud of shallow ponds. When allowed to remain in the collecting-bottle, they will often make their way to the lighted side, where some will form sheaths or protective cases from bits of *Lemna* or from various floating fragments and particles.

The mouth may be close to the front end, or at some distance back, since in a few worms the front border is extended in a long flexible snout.

The posterior border of the body is rounded in many forms, while in others it is expanded into a broad, funnel-like region, with several finger-like prominences surrounding it. In such worms these parts are ciliated on the inner side, and the currents thus produced are supposed to bring at least a portion of the oxygen needed for respiration.

The alimentary canal extends through the center of the entire body, and is usually crowded with the brownish remains of undigested food.

The whole cavity of the body outside of the alimentary canal is filled with a colorless fluid, visible only by means of the movements of the corpuscles often to be seen floating to and fro as the worm moves under the cover-glass.

The observer should not mistake this fluid for the blood, which in many of the bristle-bearing forms is red and contained in two distinct longitudinal vessels, one extending lengthwise above, the other lengthwise below the intestine. These vessels unite at both ends of the body, so as to form a long, closed tube,

with branches springing from the front part, or from the upper or dorsal tube as it passes through each segment, where they then appear as pulsating loops. Usually the blood is impelled by the regular pulsations of the dorsal vessel, a wave-like contraction passing along and driving the fluid before it. In two genera (*Túbifex* and *Ocneródrilus*) there are little pulsating hearts attached to the dorsal vessel in the neighborhood of the frontal border.

Reproduction is by eggs or by transverse fission, the latter being the most frequently observed.

Most of these worms live upon animal food, seeming to prefer Rhizopods and Rotifera to almost anything else; only a few are vegetarians.

Key to Genera of Microscopic, chiefly Fresh-water Worms. (*Oligochæta*)

1. Body with both bristles and podal spines (*a*).
2. Body with podal spines only (*b*).
3. Body with bristles only (*f*).
   a. Anterior extremity without a finger-like prolongation (*d*).
   a. Anterior extremity with a flexible, finger-like prolongation. *Pristína*, 1.
   b. Podal spines forked; worms aquatic (*c*).
   b. Podal spines not forked; worms aquatic (*g*).
   b. Podal spines not forked; worms living beneath decaying bark of dead trees. *Enchytræus*. 2.
   c. Podal spines, from six to ten in each cluster, the clusters in two rows. *Chætogáster*, 3.
   c. Podal spines, two only in each cluster, the clusters in four rows. *Lumbrículus*, 4.
   d. Posterior extremity without finger-like appendages (*e*).
   d. Posterior extremity widened, ciliated; with several retractile, finger-like appendages. *Déro*, 5.
   d. Posterior extremity ciliated; with two long, non-retractile, finger-like appendages. *Aulóphorus*, 6.
   e. Bristles and podal spines in separate rows (*h*).
   e. Bristles and podal spines alternate in the same row. *Stréphuris*, 7.

f. Body freckled with brick-red or orange colored spots; blood colorless. *Æolosóma*, 8.

g. Podal spines in clusters of four each; body the color of raw meat. *Ocneródrilus*, 9.

g. Podal spines in clusters of two each. *Lumbrículus*, 4.

h. Worm with two small anterior pulsating hearts; blood bright red. *Túbifex*, 10.

h. Worm without distinct hearts; dorsal vessel pulsating; blood pale red. *Náis*. 11.

1. Pristína (Figs. 147, 148, 149)

Body nearly cylindrical, transparent, frequently very long, and often showing that it is preparing to divide across the middle to produce two worms. In these cases the proboscis of the new worm becomes conspicuous at the center of the long body.

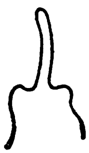


Fig. 147.—Snout of a Pristína.

Fig. 148.—Posterior extremity of a Pristína.

Fig. 149.—Posterior extremity of a Pristína.

The mouth is near the base of the snout-like prolongation, this narrow extension of the upper lip varying much in length in the various species. The one represented in Fig. 147 belongs to a common form in the writer's locality, and is unusually long.

The posterior extremity is commonly nearly as shown in Fig. 148, and is surrounded by many short stiff hairs. This is the tail-end of the *Pristína* whose proboscis is shown in Fig. 147. Occasionally the part has three long trailing appendages, as in Fig. 149.

The blood is usually red.

The bristles are long and fine, and are often accompanied by one or more short, nearly straight, rudimentary spines.

The podal spines are in two rows on the ventral surface; each cluster frequently contains as many as eight.

The posterior part of the intestine is ciliated.

The worms are found among aquatic plants, seeming especially fond of *Sphagnum* and of *Lemna* as a home. They are not rare.

2. Enchytræus

The body is white or yellowish-white, thread-like, and from about one-half to nearly one inch in length. The worms are found under damp logs or beneath decaying bark, often in considerable numbers.

The podal spines are usually short, nearly straight, and not forked.

The blood is pale or colorless.

There are two species, which are not difficult to distinguish from each other. In one (*Enchytræus vermiculáris*) the body is yellowish white, and varies in length from five-twelfths to eight-twelfths of an inch.

The podal spines are in clusters of from three to five spines each.

This species is usually found under damp and decaying logs, and is less common than the following.

In the second (*E. sociális*), the body is opalescent-white and translucent, varying from five-twelfths to ten-twelfths of an inch in length.

The podal spines are from five to seven in each cluster, the anterior fascicles generally containing seven, the posterior five.

The mouth is triangular.

This species is most frequently found, in more or less social groups, beneath the moist bark of old stumps, or in the decaying parts of trees, usually near the ground.

3. Chætogáster

Body transparent; often showing evidences of transverse fission.

The podal spines are in two rows, the clusters containing

from four to eight spines each, the spines being usually most numerous toward the posterior extremity.

The mouth is large, oblique, and surrounded by many short, stiff hairs. It is often used, when the worm is on the slide, as a sucker, then clinging to the glass and drawing the body toward it.

The intestine, in the species common in the writer's vicinity, is much and irregularly constricted, a feature which gives it the appearance of a series of various-sized pouches.

The blood is pale or colorless. The blood-vessels are distinct as narrow, pulsating, longitudinal tubes.

Chætogáster is one of the most interesting forms on account of its perfect transparency, and the absence of bristles, which allows an uninterrupted view of the whole surface, as well as of the internal organs.

4. Lumbrículus

The body is translucent, but often brightly colored at the sides or in the central parts, and may, when extended, be an inch and one-half in length. It is occasionally captured in the writer's locality, but it is never common nor abundant. Its large size, stoutness and color make it conspicuous in the microscopical aquarium, where the worm has a habit that attracts attention. It buries perhaps one-half of the body in the débris at the bottom, and holds the rest of its length above the surface, erect and rigid. Which end is thus exposed and which is concealed, I have not been able to determine, as the worm vanishes instantly at the slightest disturbance in the water, or at the slightest touch of the dipping-tube.

The blood is bright red. The dorsal vessel gives off several short, lateral, pulsating branches in each segment of the body. These short branches frequently approach the surface, and give it a mottled appearance, the spots fading and reappearing as the branches contract and expand, the movement advancing like a wave, the lateral blood-vessels in each segment of the body quickly dilating on each side at the same time, and as quickly contracting, when the movement passes on in regular order to

those in the succeeding segments. This rhythmical and beautiful movement will identify the worm more readily than any other character, especially if the body be examined under slight pressure. A shallow cell with the cover-glass gently pressed down will be sufficient.

There are four rows of podal spines, with but two spines in each cluster, each being curved, forked at the end,* and with an enlargement or shoulder near the center.

The microscopist may experience some difficulty in detecting the four series of podal spines, unless the worm is subjected to considerable pressure. Even then the two inferior rows may not be easily seen. The podal spines are small, measuring when isolated from the body, only about 150μ, or $\frac{1}{167}$ of an inch in length. They are but slightly curved, the median enlargement or shoulder is small and inconspicuous, the bifid termination is minute, hardly more than a mere notch, and this slightly forked tip projects for only a short distance beyond the surface of the body. None of these characteristics favor easy observation, but *Lumbrículus* is an interesting worm. It will repay the time and attention that the microscopist may devote to it.

At a short distance from the attached end of each pair of spines is often to be found another pair which are small, and may be overlooked on the front of the body, when the worm is not dividing transversely. When it is undergoing transverse fission, the posterior part may be so well supplied with these small secondary podal spines, that their number and arrangement may confuse the observer. The rows then appear to be eight, with two spines in each cluster, or four rows with clusters of four spines each. If the microscopist will examine the front half of the dividing worm, and be guided by the podal spines there, and will note the peculiar arrangement of the blood vessels, he will not long remain in doubt as to the identity of the specimen.

* Since this was written a species has been observed with undivided podal spines. It has been included in the Key.

5. DÉRO (FIG. 150)

The posterior extremity is broad and funnel-like, its upper plane often being oblique. Its inner surface is finely ciliated, as are the finger-like projections, and the internal surface of the posterior part of the intestine, which is connected with it and forms a portion of it. The cilia produce currents over these parts which are supposed to absorb the oxygen for purposes of respiration.

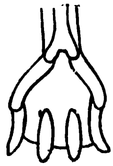


FIG. 150. — Posterior extremity of a Déro.

The finger-like processes vary in number from two to eight. They can be elongated or drawn back into the funnel, which can also be retracted and almost closed. When extended they may be much longer than the funnel-like termination of the body, or they may not reach to its margin.

The blood is red.

The podal spines vary from three to five in each cluster.

These worms are often found on the side of the collecting-bottle after it has been standing for some time. Usually they bury themselves in the mud, with the posterior part of the body, and the expanded funnel-like region protruding from small mud-chimneys of their own formation. The body may measure half an inch or more in length.

6. AULÓPHORUS (FIG. 151)

The posterior extremity, not wider than the width of the body, bears two, long, finger-like appendages that may be straight or slightly curved. They are usually blunt, and are well supplied with short, fine, bristle-like hairs. In addition to these two appendages, the posterior margin of the body is encircled by a series of several rounded processes (papillæ), densely ciliated.

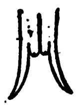


FIG. 151. — Posterior extremity of an Aulóphorus.

The podal spines vary from five to nine in each cluster. The fascicles of bristles are each accompanied by from one to three rudimentary spines, nearly straight, and ending in a broadened, spade-like expan-

sion. The bristles in each cluster are few in number, not rarely being reduced to one only.

The worm usually builds a tubular sheath of various fragments and floating particles, in which it lives, but to the walls of which it is not adherent, as it sometimes doubles on itself, glides through the tube, and thus reverses its position.

The blood is pale red.

Prof. Joseph Leidy, who discovered the worm and named it *Aulóphorus vágus* (the wandering pipe-bearer), says that it moves by jerks, alternately extending the fore part of the body and projecting the podal fascicles forward, and hooking into the surface on which it is creeping, and then contracting the fore part of the body and dragging along the back part enclosed within the tube. It also often helps itself along by clinging to the slide by its protruded throat, or pharynx.

Dr. Leidy first found *Aulophorus* in material that he had scraped from the surface of a submerged, water-logged tree-trunk. It occurs occasionally in the writer's locality, but at long intervals. I have taken it from among aquatic plants in the open water.

7. STRÉPHURIS (FIG. 152)

The podal spines and bristles are arranged alternately with each other, as in FIG. 152, and together form a single row of clusters on each side of the lower surface of the body. The spines are slightly curved, long and forked; the bristles are three times their length.

FIG. 152. — Podal spines and bristles of Stréphuris.

The mouth is triangular.

The blood is bright red and the vessels are large.

The body is thread-like, transparent, and may be from one to two inches in length. The front end is whitish, the tail end yellowish.

It lives in the mud beneath shallow water, and buries itself with about two-thirds of the tail end protruding and constantly vibrating. When disturbed it disappears into its burrow with astonishing rapidity.

Dr. Joseph Leidy, who discovered this peculiar creature, says: "While walking in the outskirts of the city (Philadelphia) I noticed in a shallow ditch numerous reddish patches of from one to six inches square, which, supposing to be a species of Alga, I stooped to procure some, when to my surprise I found them to consist of millions of the tails of *Strêphuris ágilis*, all in rapid movement. The least disturbance would cause a patch of six inches square so suddenly to disappear that it resembled the movement of a single body."

8. Æolosóma

The bristles on the sides of *Æolosoma* are slender and, on account of the worm's movements and the high magnifying power needed, it is not easy to ascertain their number, but they vary from four to six or eight. On the front of the body several fascicles are coarser, and are arranged somewhat like the ribs of a palm-leaf fan. There are none in advance of the mouth.

The mouth is large, U-shaped, with the arms of the U pointing forward.

The pharynx is broad and ciliated within.

The body is colorless, but the freckles that are sprinkled irregularly in rounded spots over the sub-cutaneous tissue, unlike those so often sprinkled on the cutaneous tissue of the boy's face, are brick-red or orange colored, and give the worm a beautiful and characteristic appearance, as the brown freckles add to the pleasing and piquant appearance of the boy.

Æolosóma, and sometimes the boy, too, is found in ditches and similar places, among decaying Algæ, on which the worms feed.

They appear to favor the depths of stale or partly decayed collections of aquatic plants left standing in the light and warmth of a room, occasionally presenting themselves in abundance in such places. On a mass of *Sphagnum* which had been gathered several months before, and had remained in a covered vessel until the water was thickly coated with a slimy mass of microscopic fungi, the worms glided in great numbers, and seemed

there to find a plentiful supply of food. More recently they have developed in such quantities in an old infusion of dead autumn leaves that the small and thread-like bodies became conspicuous to the naked eye by reason of their numbers.

The food consists chiefly of the decaying parts of plants, with the fine débris which collects at the bottom of the water. These matters are seized by a snapping motion of the mouth and lower lip. Animal food appears to be taken by accident only, and consists chiefly of Rhizopods.

The inner surface of the intestine is densely clothed with fine cilia.

Under the thin-glass cover the worm is noticeably active in its movements. With a comparatively high magnifying power (the $\frac{1}{8}$ inch), it is out of focus as soon as it is in.

It increases rapidly by transverse fission.

The blood is colorless.

Among the *Sphagnum* in the writer's locality, an *Æolosoma* not uncommonly occurs that differs externally from the ordinary form, in having fewer and larger, red freckles that seem to be on the outer surface of the body and most abundantly collected near the two extremities. Its movements are also much more active. The two are probably the same species, or the one is only a local variety of the other.

9. Ocneródrilus

The remarkable worm has thus far been found, by Dr. Gustav Eisen, who discovered it, only in Fresno County, California It was obtained from among fine Algæ growing to the sides of a submerged wooden box, and occasionally in the mud, with a part of the tail end protruding and motionless.

The body is rather less than an inch in length, one-twelfth of an inch wide, and presents the peculiar color mentioned in the Key. Its movements are slow.

The podal spines are slightly curved, but not forked at the ends. They are arranged in clusters of four spines each, the clusters forming two rows, one on each side of the body.

The œsophagus is long and remarkably muscular. It is

surrounded and somewhat obscured by a pair of large glands, and has near its posterior extremity two large appendages similar in structure to the œsophagus itself.

The blood is yellowish-red.

The dorsal vessel divides, at some distance behind the front end of the body, into three branches, which pass forward, and near the anterior border unite by means of a network of fine tubules.

The worm has four hearts, two on each side of the dorsal vessel, one pair near the eighth, and one pair near the ninth cluster of podal spines. The dorsal vessel divides in front of the first pair of hearts.

. The ventral blood-vessel is forked but with only two branches.

10. Túbifex

A common and, in some places, very abundant little worm, measuring from ½ to 1½ inches in length. The body is thread-like in its narrowness, transparent and colorless, although the bright crimson blood gives it a hue so vivid to the naked eye that, where the worms are numerous, it often seems to tinge the mud in which they live.

They are seldom found free-swimming. They live a comparatively sedentary life, with about one-half of the body concealed in its burrow, the remaining parts protruding into the water, and constantly waving to and fro beyond the edge of the little tubular chimneys which it erects.

These little towers are often conspicuous objects on the surface of the mud in shallow still water, the worms instantly disappearing into them at the slightest disturbance.

Among certain French and German writers on the subject, there is a difference of opinion as to which end of the worm is buried and which end protrudes into the water. As the protruding parts are continually moving, and as the worms dart into the mud with such astonishing swiftness, to decide the matter is rather difficult. It is, however, probably the tail end.

The bristles are comparatively short, and appear to be arranged in a single row on each side of the body, whereas there

is really an additional row of podal spines on both sides of the worm. These podal spines are entirely retractile, and may be overlooked unless specially searched for. Even then it will perhaps be necessary to compress the worm rather forcibly between the slide and the cover-glass, before they will become conspicuous. They are but slightly curved, and appear to be forked.

With high magnifying power some of the bristles present a peculiar aspect. The free extremity is widened and forked, but the two prongs of the fork are apparently connected by a thin membrane longitudinally striated. Sometimes this membrane splits into fine hairs. These widened bristles are most frequently seen on the young worms.

The bright red blood is contained in two principal tubular vessels, one above, the other below the tortuous intestine. The upper, or dorsal one, has connected with it near the anterior end of the body, two little contractile hearts, one on each side which can be seen through the hyaline animals. They throw out the blood with considerable force. The two vessels are connected with each other by smaller branches, a pair in each segment or body-ring, one on each side.

There is also on each side of the body—two in every segment—a narrow colorless tube, ciliated within, and resembling those found in *Nais* and in other aquatic worms. They are most conspicuous in the posterior rings, and are supposed to represent kidneys in function.

Túbifex is reproduced by eggs, which probably make their escape after the parent's death, and after the body has fallen to pieces, as the living creature has no natural passage for their exit. Huxley says that they pass out through the segmental organs—the ciliated tubes, referred to in the preceding paragraph as representing kindeys in function.

11. NÁIS (FIGS. 153, 154)

The body of *Nais* is whitish or yellowish, and usually active.

The podal spines and the bristles are each arranged in a row on each side of the worm; the bristles near the front end

are usually the longest. Each cluster of podal spines contains four or more.

The mouth is round.

The front border of the body bears numerous, fine, short hairs.

Two dark or black eye-spots are generally present, one on each side and in advance of the mouth.

The blood is red.

Many of the narrow, colorless tubes, already referred to, with a ciliated lining, are to be noticed on both sides of the intestine. They are much looped and twisted, and are supposed to play some part in respiration, and to represent the

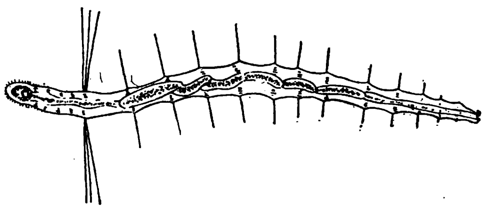


FIG. 153.—Náis.

FIG. 154.—Podal Spine of Náis.

kidneys of animals higher in the scale. They are bathed in the colorless fluid filling the cavity of the body, and float out of position rapidly, as this fluid flows to and fro, following the movements of the worm.

Náis is one of the commonest of our aquatic worms. It is frequently found among Algæ in shallow water, or on the leaflets of various plants, especially, according to the writer's experience, in *Sphagnum*, in company with *Pristina* and *Chætogaster*.

The literature of the aquatic worms is widely scattered in the scientific magazines, and in the Proceedings of learned societies. There is no comprehensive English treatise on the subject, except the "Monograph on the Oligochæta," 4to, London, by F. E. Beddard, a learned, strictly scientific work scarcely adapted to the needs of those readers for whom this book is intended.

CHAPTER VIII

ROTÍFERA

When these transparent microscopic animals are swimming or taking food, there is usually an appearance of two, small, rapidly rotating wheels on the front border of the body, an appearance that suggested the name of Rotífera, or Wheel-bearers, for the group.

The two organs certainly seem like rapidly revolving wheels, when viewed under a low power, but they are in reality two discs or lobes bearing marginal wreaths of fine cilia, which vibrate so quickly that the eye can usually perceive only the effect. It is by the action of these cilia that the Rotifer swims and captures food, the currents produced by them, when the animal is at rest, setting in toward the mouth, that is often situated between the ciliary (or cilia-bearing) discs, and carrying particles of food which the Rotifer accepts or rejects.

As a rule, the ciliary discs are two separate organs but they may be united into one, or the Rotifer may have the front margin of the body bordered by a single series of cilia, or the discs may be entirely absent and replaced by long, ciliated arms, as in *Stephanóceros*, or by clusters of long, fine hairs as in *Flosculária*, both of which are Rotifers, or the cilia may be restricted to a band on the lower, the ventral surface of the body.

Most of these animals have eyes at some period of their life, or little red or black specks supposed to have the function of imperfect eyes. They are often to be noticed near the front of the body in young individuals, but from the old they are as often absent. Their number and position have sometimes been used as characters by which the genera and species have been classified but, since they often disappear with age, they can have little value for this purpose, certainly none to the novice.

The eyes, when present, are almost without exception attached to the brain. This in some Rotifera is an enormous organ, often filling most of the front region in advance of the eye. Such Rotifera should be among the most intelligent of animals, if intelligence is ever commensurate with mere mass, and not with quality and fineness of structure. In some, the eyes appear to be directly adherent to the jaws, or to what is called the mastax. In others, each eye is connected with the brain by means of a thread-like nerve, often difficult to detect. In all the Rotifera a nerve ganglion is present and acts, as is supposed, as a brain. The eyes are in some direct way connected with it.

The body is inclined to be cylindrical, yet there are some that resemble flat discs and oblong figures.

Neither are they all free-swimming. Some are permanently adherent to the leaflets of aquatic plants or to other submerged objects. These generally form a protective sheath about themselves, into which they retire when frightened or disturbed, in a manner similar to that of some Infusoria; and, as the infusorial lorícæ, the sheaths may be formed of a stiff membrane, or of the softest and most gelatinous material, or they may be built of particles of flocculent rubbish, or of rejected food-fragments. In all instances the sheath is the work of the Rotifer inhabiting it.

Few sheath-bearing Rotifera are free-swimming. Only three .such are known to exist. These were discovered in England. One of them (*Flosculária mutábilis*) has been found in Lake Erie; there is in this country no record of the other two.

Most of the unprotected, free-swimming forms may become temporarily adherent by means of their foot and toes.

The body of these free-swimming forms may be soft and flexible, and without any greater protection than is afforded by the skin, or it may be enclosed within a hard, shell-like coating called a lorica.

The body of every sheath-building Rotifer is without a lorica, the sheath or tube acting as a sufficient protection. In the other kinds, the lorica is as colorless and transparent

as a glass box; all the creature's organs are plainly visible through its walls. The front part of the body, which bears the cilia or the ciliary discs, and often the long tail-like prolongation of the posterior part, can be drawn within it, and the Rotifer thus be shut in and protected from harm. The soft-bodied forms have a similar habit of drawing in the two extremities, taking advantage of the hardened skin. This is one of these animals' characteristics.

The long tail-like part at the posterior end of the body is called the foot, and the one or more short divisions at the free end of the foot are the toes.

The true tail is usually a small affair, which the observer should not mistake for the more important foot, although it is placed on the foot, sometimes near the body and is apparently a continuation of it. It may be represented by a single short point; it may be in two parts and rather conspicuous; or it may be entirely absent.

The uses of the foot seem to be to act as a rudder to guide the Rotifers when swimming, as they do in a hurried, headlong way, and to anchor them when they desire to fish for food; the toes then adhere to the surface of the slide or other object and hold the animal against the propelling power of the ciliary discs.

In some of the group, especially in the commonest of all—*Rótifer vulgáris*—the whole foot is arranged with joints, that slide on one another like the joints of a spy-glass. In this and in similar forms the Rotifer can not only swim, but it can crawl or creep like a leech, by fixing the front of the body against the slide, drawing in the telescopic joints of the foot, and clinging with the tips of the toes; the front is then loosened, the foot extends and carries the body forward for a short distance, when the action is repeated. A Rotifer can do this with surprising rapidity, and travel over considerable microscopic distances in a short time.

The mouth is usually placed between the two ciliary discs, when they are present, or near the center of the frontal portion of the body, or, in many forms near the front, but on the lower

surface of the animal. Those Rotifera with the mouth in the last-mentioned position, usually feed by gliding along with the front of the body in contact with the plant, tearing and biting off small particles as they go. These may be called the nibbling Rotifera. They form by far the greater number of known species.

Following the mouth is usually a tubular passage leading to a pair of wonderful jaws inside of the body. These with a low-power objective, can be seen in action through the transparent tissues of the animal.

The jaws are always present in the creatures, and are a great help to the microscopist, for as soon as he observes them pounding and crunching away inside of a transparent, legless, microscopic animal, he may be sure that his specimen is a female Rotifer. The ciliary disc may be absent, or replaced by arms, or hairs, or by some other substitute, but if these internal jaws are present the specimen is a Rotifer, and can be nothing else.

By some observers these remarkable organs are called the gizzard, which they are not. The best word to apply to them is *mastax.* It is the animal's true mouth; the passage leading to it from the frontal region is only a part of the preoral tract.

The mastax is the most hard-working part of the creature's anatomy, except, perhaps, the cilia. When the currents produced by the latter bring an acceptable morsel of food to the preoral aperture, it is passed down to the mastax, where it is crushed, and allowed to go on to the stomach.

In some Rotifera the part is complicated. In the simpler forms, it consists of two apparently semicircular or oblong plates surrounded by a thick envelope of powerful muscle, the flattened sides of which act against each other and crush the food between them. The surface of each plate usually bears several transverse ridges, to be seen with a high power, each ridge projecting for a short distance beyond the straight internal edge, and forming low teeth. These ridges, when the mastax is closed, are received in the depressions or furrows between those on the opposite plate, and thus make an effectual crushing instrument. The plates are transversely and finely

striated. These lines are plainly visible with the $\frac{1}{4}$- or the $\frac{1}{8}$-inch objective. They should not be mistaken for the teeth, as perhaps they may be on first acquaintance. The true teeth are large, robust, heavy, microscopically heavy, ridges. Usually they are parallel; sometimes, however, they slightly diverge from one another.

In other forms of the mastax, these hard, horny portions, commonly referred to as the trophi, consist of three parts, one being immovable, and used as an anvil, on which the other two pound the food as it passes by. In the nibbling Rotifers the entire mastax is protruded through the preoral aperture, and bites, tears, and nibbles at acceptable food-masses.

If the observer find it difficult to make out the form and structure of the mastax, as he probably will when it is examined in action within the body, he may succeed in isolating the organ by killing the Rotifer with a strong solution of caustic potassa allowed to run under the cover-glass, a small drop at a time. This will dissolve the soft parts, and permit the hard, insoluble trophi to float out, when they may be examined with a high-power objective. Seven kinds or types of these organs are described by microscopical anatomists.

The contractile vesicle is present in the Rotifera, and is usually prominently developed and displayed, although in some forms, notably in *Pterodina* (FIG. 165), it is small and must be specially looked for, or it will not be seen. Its presence in *Pterodina* has been detected there by several observers, the writer among them.

The organ in the majority of the Rotifera is usually placed in the posterior part of the body, where it empties into the posterior part of the intestine. As the vesicle contracts, the intestine may be seen suddenly to expand, and in its turn to collapse and become as invisible as it was before. The vesicle and its movements may be well observed in the common Rotifer (*Rotifer vulgaris*).

The Rotifera are reproduced by eggs, that are sometimes hatched within the parent's body, when the animals are said to be ovo-viviparous. This, however, is not common. The eggs

are usually semitransparent, ovoid bodies, often to be seen on the slide among other matters, with the enclosed Rotifer imperfectly developed, and the mastax grinding away inside of the unhatched body, where it cannot possibly have anything to crush. The only parallel to this, of which the writer knows, is Professor Agassiz's statement that the jaws of the young snapping-turtle snap while the creature is still within the egg.

The Rotifers may drop their eggs anywhere and leave them to the care of Nature, or they may prudently attach them to a submerged leaf or to some other aquatic object. Very often they are adherent to the posterior part of the parent, and are carried about until the young are hatched. In those permanently attached Rotifers that form a soft sheath, this is a common occurrence, and several eggs may at almost any time be seen in the lower part of the sheath, or adherent to the animal's foot. In such instances, when the young are hatched, they creep up between the parent's body and the side of the sheath, and escape at the front, or, not rarely, bore their way through the wall of the flocculent tube. They swim about for a short time, and then secrete or build a sheath of their own, which they never voluntarily leave.

The eggs are usually smooth; sometimes, however, they are covered with short spines or hairs.

I have several times witnessed the escape of the Rotifer from the egg. The act is usually accomplished quickly. The enclosed animal breaks the imprisoning membrane by a strong push, and quickly swims away. On one occasion, and on one only, I saw the young Rotifer (in this instance an undescribed and unnamed species), deliberately swallow the egg-membrane from which she had just escaped. Steadily and without interruption, the membrane was drawn into the body by the action of the mastax. It was not torn into shreds, as might be imagined would be necessary, but was swallowed as an unbroken sheet.

It is a peculiar and interesting fact, that although there are male and female Rotifers the males are seldom seen. In some species they have never been found, and are therefore entirely

unknown. Those that have been discovered are much smaller than the females of the same species; they are always free-swimming, and are without a mastax and an alimentary canal, or with the latter so imperfectly developed that it is useless. Male Rotifers never take food. It is not probable that the reader will meet with them, or at least that he will recognize them as the males, or indeed as Rotifers, for some bear only a remote resemblance to the female.

This group of microscopic animals is almost as common and abundant as are the Infusoria. They are found in similar places. They are specially fond of hiding in masses of *Myriophyllum*, or among the leaflets of any other aquatic plant. Almost any pond or shallow body of still water may be examined with a certainty of finding them. They have even been sparingly obtained from the moss that grows between the bricks in damp pavements. Some species develop in vegetable infusions, but as a rule they prefer pure water.

Dr. C. T. Hudson, in Hudson and Gosse's monograph on "The Rotifera, or Wheel-animacules," speaking of the varied and dissimilar places favored by these microscopic animals, says: " Rotifera may be found in rivers, lakes, reservoirs, ponds, ditches, puddles, gutters and water-butts; in the mud of dried ponds; in the dust of dried house-gutters; on wet moss and grass; in the rolled-up leaves of liver-worts; in the cells of *Volvox globator* and of *Vaucheria;* in vegetable infusions; on the backs of *Entomostraca*, and of fresh-water fleas, wood-lice, shrimps and worms; in the viscera of slugs, earth-worms, and *Naiades;* and in the body-cavities of *Synaptæ*. Nor have I yet completed the list; for several species have been found in the sea. Mr. Gosse says, ' *Synchæta Baltica* swims at large through the water, never resting; it is self-luminous, and is one of the causes of the phosphorescence of the sea.' To obtain some particular Rotiferon, at a particular given time, is often difficult enough, if not impossible; but for one who is content to study these beautiful creatures as he finds them, there is always a never-ending supply of delightful amusement."

A good method by which to capture them for the microscope,

after a pond-hunting expedition, when we may be sure that we have the creatures somewhere in the vessel, is to take a portion of a plant carefully out of the gathering, and rinse it in a watch-glass full of water, preferably in the water which will drip from the plant, or which may be dipped from the collecting-bottle itself. The Rotifers will surely be washed from among the leaflets, and may be captured by the dipping-tube. If left on the table near a window they will, like most other microscopic creatures, both plants and animals, in a short time collect on the lighted side.

They may also in this way be successfully collected from the pond. Draw the submerged plants gently to the waiting dipper, in which they should be rinsed by repeated rinsing and a final squeeze. This method is of course adapted only to the free-swimming forms. The adherent Rotifera must be searched for by examining the leaflets to which they may be attached.

The reader will not expect to find all the genera and species included in this book. He will obtain many whose names he cannot hope to learn in this short account. He can know them to be Rotifers by the presence of the mastax, that makes them one of the most easily recognizable groups of microscopic animals, and one of the most interesting classes of creatures for microscopical study.

Few of our American forms have been carefully investigated. There is no American treatise on the subject to which the reader can be referred.

It has been said that for the correct observation of the Rotifera there are only two directions to be given: First, to see them alive; second, for reagents, use patience.

But Mr. J. D. Hardy has found that the best way in which to keep them quiet is to make a strong solution of common loaf-sugar, and add it drop by drop to the water, until their rapid motions are stopped. This does not prevent the ciliary action, but it restricts the animal's rapid movements, so that it may be studied. The syrup should be about as thick as treacle. The Rotifer's freedom of action may be restored by the addition of water to the cell.

The solution of cherry gum recommended in the study of the Infusoria acts well with the Rotifera, restraining their movements but doing them no injury.

In using the following Key, the reader should bear in mind that the mucilaginous sheath of some of the Rotifera is usually colorless, and rather difficult to see distinctly, unless it have particles of rubbish, or of other extraneous matters, adherent to it. At times it may be almost as conspicuous as the animal that it encloses. The Key refers only to those forms included in this book.

Key to Genera of Rotífera

1. In an attached, gelatinous or other kind of sheath (*a*).
2. Not in a sheath, but in attached clusters (*d*).
3. Free-swimming, singly or in a clustered group (*e*).

a. Clustered; sheaths soft, gelatinous, colorless; ciliary disc single, heart-shaped. *Lacinulária*, 1.

a. Not clustered, but sometimes in family groups; sheath gelatinous (*b*).

a. Not clustered; sheath not gelatinous (*c*).

b. With five long, erect, ciliated arms on the front border. *Stephanóceros*, 2.

b. With several (from 2 to 7) groups of many long, fine, radiating hairs (setæ) on the front border. *Flosculária*, 3.

b. With a broadly oval or circular ciliary disc; sheath gelatinous, semi-opaque, or with pellets. *Œcístes*, 4.

c. Sheath formed of rounded, brownish pellets. *Melicérta*, 5.

c. Sheath not formed of pellets, but membranous; brownish or colorless. *Límnias*, 6.

d. Ciliary disc horseshoe-shaped. *Megalótrocha*, 7.

e. In a cluster of coherent, gelatinous tubes; ciliary disc horseshoe-shaped. *Conochílus*, 8.

e. Not clustered; with lorica (*g*).

e. Not clustered; without lorica; ciliary discs two (*f*).

f. Eyes two, cervical. *Philodína*, 9.

f. Eyes two, on the front column (proboscis); teeth two in each jaw; toes three, the middle one small and not easily seen. *Rótifer*, 10.

g. Lorica with a visor-like projection in front. *Stéphanops*, 11.
g. Lorica circular, flattened; foot long, cylindrical, retractile. *Pterodína*, 12.
g. Lorica vase-shaped; foot long, with two exceedingly long toes. *Scarídium*, 13.
g. Lorica with 6 long, narrow, movable, oar-like appendages on each side. *Polyárthra*, 14.
g. Lorica with several tooth-like spines on the front border. *Brachiónus*, 15.

1. Lacinulária

The clusters contain numerous individual members, which secrete a common, soft, colorless, or pale yellowish, and short sheath with no special shape. This formless jelly-like enclosure surrounds only the posterior portion of the colony, where it must serve as an exceedingly inefficacious protection, if it serve any.

The Rotifers themselves are somewhat trumpet-shaped when extended, and to a certain extent resemble *Megalótrocha* (Fig. 160). The ciliary disc is single, horseshoe shaped and oblique. It is closed and drawn partly into the body, when the Rotifers retire into their apology for a sheath, as they often do, the whole colony continually waving and bobbing and bowing as the members retire, or ascend to expand themselves, the sheaths usually forming a little mass of jelly-like substance, from all parts of which the Rotifers project.

The colonies are commonly adherent to *Utricularia* or to *Myriophyllum*, and are often visible to the unaided eye as grayish little balls.

2. Stephanóceros (Fig. 155)

The body of this, the most beautiful of all the Rotifera, is somewhat spindle-shaped, and ends in a long, flexible, tail-like foot which is attached to some submerged object. It has its characteristic feature in the five long, slightly curved arms arranged in a row about the edge of the front border. These arms are held aloft, and form a beautiful object for the micros-

copist, and an effectual trap for wandering Infusoria, which are attracted or drawn into it by some means not easy to make out but really accomplished by ciliary action difficult to observe.

The front of the body is a deep, open funnel leading to the preoral aperture, to the mastax, and to the stomach. The ordinary ciliary disc is absent, being replaced by the beautiful arms, but around the lower inside border of the funnel-like front, are many fine cilia that produce the currents in the water by which the living food is drawn to the trap. These cilia are exceedingly fine and difficult to see, even with a high-power objective.

FIG. 155.—Stephanóceros.

The sheath is usually colorless and transparent, but with considerable firmness. It often surrounds the body up to the origin of the arms.

When a small animal once enters the cage formed by these arms, beautiful objects as they are, it seldom escapes, but is gradually driven into the funnel, when the Rotifer partly closes the front opening, and with a perceptible gulp, swallows the captive and passes it on to the mastax.

Stephanóceros is not common. The writer has found it sparingly on *Myriophyllum* as late as the middle of November, but never at any time in any abundance. It seems to be much more plentiful in England. Mr. Lewis Wright in his book entitled "A Popular Handbook to the Microscope" (London, 1895), says that he has had long filaments of *Spirogyra* thickly studded from end to end with *Stephanoceros*.

3. FLOSCULÁRIA (FIG. 156)

The front of the body, the preoral passage, is here like an open funnel, the narrow part leading to the mastax. The ciliary disc is, in the species here referred to (*F. ornáta*), replaced by five little rounded elevations on the front margin, each bearing a dense cluster of long, fine, radiating setæ, that are flexible,

and movable at the animal's will, but that never vibrate like cilia.

The long foot is attached to a submerged object, and is surrounded by a soft, transparent sheath.

When the Rotifer retires into this protective covering, it folds the wide front part of the body together, the clusters of long setæ appear to become much tangled into a single bunch, and the creature slips back into the sheath.

When she comes out, the bunch of setæ trembles in a charming way, reminding the observer of that quivering of hot air so often seen above a warm surface on a summer day. The front border opens, the clusters of stiff hairs are spread apart, and the Rotifer is ready for something to eat. Any little animal that may be acceptable as food, slipping in between the setæ seldom comes out again. The *Floscularia* gently contracts the frontal opening, and directs the victim toward the preoral aperture where it is gulped down as in *Stephanoceros*, and the mastax finishes it.

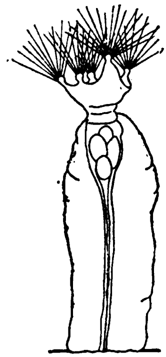


FIG. 156.—Flosculária ornáta.

Several eggs are often to be seen attached to the foot.

On the inner surface of the broad, funnel-like region, named the "buccal funnel" because it leads to the mouth, is a narrow, horseshoe-shaped band of short, fine cilia, whose vibrations produce those mysterious currents already referred to, that lead toward the mouth, and carry with them any small object that the *Floscule* has accepted as a food-morsel. These cilia are exceedingly minute; the band that they together form is narrow, and extends for not more than one-half of the distance around the base of the buccal funnel. It is situated on the ventral, the lower side of the animal, far down within the funnel, and ends at each extremity in a minute knob, both of which bear several long fine cilia. While it is not difficult to observe the ciliary currents, to see the exceedingly minute cilia themselves is a microscopical feat of no small proportions.

They can be distinguished only when the animal is in a favorable position, and when the buccal funnel is widely expanded. Unless the observer can look directly into the buccal funnel, as he can rarely do, since the animal seldom places itself in so favorable a position, he must see those fine cilia through the thickness of one side of the body. This, in addition to their minuteness and their rapid movement, increases the difficulty. But they may be seen with a ¼- or a ⅛-inch objective.

This ciliary rim is worth looking for and worth seeing, not because there is anything theatrical or spectacular about it, but because it is so difficult to detect, and demands so much care and patient observation for its successful definition. When the microscopist has once conquered it, he will feel like a microscopical hero.

A similar band is in a similar position within the similar part of *Stephanoceros*, where it may be seen with equal, perhaps with even greater difficulty.

This splendid *Floscule* is common, and where one is found others will usually be near by, as most of the species are wonderfully prolific.

Within the tube of a single individual of the species (*F. coronetta*), the writer has seen thirteen eggs, in various stages of development. To find three is not uncommon. A microscopical aquarium will, in favorble circumstances, soon become bountifully supplied with these beautiful creatures.

From a small glass jar seven inches high and about six in diameter, containing as its only plant a handful of *Elodea*, the writer has taken at almost every plunge of the dipping-tube a splendid specimen of *F. coronetta* in vigorous life, and with an apparently insatiable appetite. The jar had been rather carelessly filled with the plant late in October (central New Jersey), and *Floscularia* was delightfully abundant during all of December.

4. Œcístes (Fig. 157)

When a bottle of pond water containing various plants is allowed to stand for a while undisturbed, there will often form on

the sides delicate, thread-like objects, frequently branching and otherwise resembling brownish Algæ and waving and trembling as the bottle is stirred. They are so soft that the dipping-tube can hardly remove them without breaking them. These are the sheaths of a Rotifer, which she makes from a sticky secretion exuded by her body, combined with small particles of any kind that may be floating in the vicinity. The inner surface seems to be smooth, but the outside is always rough, irregular, and flocculent.

FIG. 157.—Œcistes.

The ciliary disc is here not divided into two lobes, each with a rapidly vibrating wreath of cilia, but is a single lobe in the form of a wide oval, with the ciliary wreath on its edge. There are two rows of cilia, but to see the two distinctly is no small task for the microscopist, as they are minute and always in rapid motion.

The Rotifer projects from the open end of the sheath, and clings to the supporting object by means of an expanded, sucker-like foot. As the tube lengthens by the deposit of new material at the summit, she takes a step forward so as to keep her expanded ciliary disc in the open water.

If the student will allow a mixture of pulverized indigo and water to run under the cover-glass, he may witness the formation of the sheath. A blue ring of indigo will speedily appear at the top of the soft tube.

Several kinds of Algæ surround themselves by a jelly-like substance in which they live and grow. One of the commonest of these is *Chætophora* (Chap. III), but there are others almost as common. These little gelatinous bodies vary from the size of a shot to that of a cherry, and are often so abundant that they fringe and ornament the narrow leaflets of aquatic plants with glistening green globules like dewdrops on a spider's web.

These mucous spheres are occasionally inhabited by an *Œcistes* (*Œ. socialis*), that takes advantage of the jelly and domiciles herself within it as within a protective lorica, instead of forming a sheath for herself. In a little mass of the kind, perhaps the $\frac{1}{30}$ of an inch in diameter, I have seen a colony of nine individuals of this species, only about one-half of the body projecting into the water, the animal speedily retreating into the jelly on the slightest provocation.

The ciliary crown is small, almost circular, and only slightly wider than the body.

The foot is twice as long as the body, and terminates in a disc, by which it adheres to the supporting plant.

The mastax is small, and in incessant, almost violent movement. The teeth are unusually minute and inconspicuous, and on account of the activity of the organ, are difficult to count, but there are four in each jaw, with numerous supplementary transverse ridges.

Some species of *Œcistes* have a conspicuous hook, sometimes a long, branching, antler-like hook, on the back of the neck. The species with the cervical antler, *Œ. melicérta*, is frequently met among aquatic plants in the ponds. In *Œ. socialis* there is on the neck only a minute antenna, like a pointed pimple, difficult to find even when the lively creature is comparatively quiet.

5. MELICÉRTA (FIG. 158)

The sheath of *Melicérta* resembles that of no other common Rotifer. It is built of pellets, which she makes and places in rows around her body, thus erecting a reddish or yellowish-brown lorica that cannot be mistaken.

The body itself is colorless, and is always attached to an aquatic support by the tip of the long foot. The ciliary disc or corona consists of four parts or lobes of different shapes and sizes and the little creature has in addition to these a peculiar and rather complicated organ for making the pellets.

The whole front part of the body can be folded together into a rounded mass when *Melicerta* is frightened and retires

into her sheath. When her fright is over, she slowly protrudes this rounded mass from the aperture, gradually spreads it open, sets the cilia at work, and proceeds to eat and to build. The last she seems to do almost continuously, up to a certain point, for as her body grows, her house must be enlarged and lengthened to receive it.

The ciliary disc of *Melicerta* will repay the most careful study, and careful observation will be needed to learn just how the three distinct currents that she makes in the water are produced. One current brings food-particles to the mouth, whence she selects the acceptable morsels and passes them on to the mastax; a second current carries away the fragments for which she has no use; and the third sets in toward the little organ that makes the pellets.

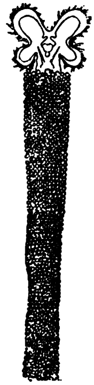


FIG. 158.—Melicérta ríngens.

This pellet-making organ is a small cavity into which the building material is poured, and in which it is turned about rapidly by the fine cilia that line it. An adhesive secretion is exuded that causes the particles to adhere to one another, and the revolving motion gives the pellet the shape of a Minié-bullet, or, in another species, makes them spherical.

When the pellet is formed to the Rotifer's liking, and all is ready for the final act, *Melicerta* rotates or twists herself in the tube, bends her body forward, and deposits the pellet on the top row exactly in the right place, and there she cements it fast with an invisible, insoluble cement. The entire act is performed so quickly, that when the observer sees it for the first time, he is so surprised that he sees nothing. It is a remarkable fact that, as a rule, *Melicerta* forms a pellet, while standing at that side of the sheath opposite to the point where she intends finally to place it.

There are two somewhat common species in our waters, one making almost spherical pellets (*Melicérta ríngens*), the other forming her "bricks" in the shape of the Minié rifle-bullet

(*Melicérta conífera*), with the conical extremities pointing outward.

6. Límnias (Fig. 159)

The attached sheath formed by this Rotifer is a rather rigid, always membranous, and nearly cylindrical tube, somewhat widest in the upper region. When young it is usually colorless and smooth, but it changes with age, becoming brown or blackish, and floating particles roughen it by adhering to the outer surface.* The animal living within it is colorless.

Fig. 159.—Limnias ceratophylli.

The ciliary disc is divided into two lobes, which the owner folds together when frightened, or is forced to retire to the lower regions of her domicile for protection.

The sheath is secreted from the body of the occupant. It is not built up of particles picked out of the currents that flow from the ciliary discs; neither is it, as with some other forms, composed of fæcal matter.

Limnias is not rarely found attached to the leaflets of *Ceratophyllum*, and is probably named *Límnias ceratophýlli* for that reason, although it is as often to be obtained from *Myriophyllum* or *Elodea*.

Another species of *Limnias* also rather common in the writer's locality, differs from *Límnias ceratophýlli* in having the sheath apparently formed of narrow rings, so that its edges, as seen under the microscope, appear to be finely waved, or scalloped by the ridges that encircle it at regular intervals. By this character it may easily be distinguished from *L. ceratophylli*. It is *Límnias annulátus*.

The distance between the ridges varies in different specimens. In some they are 7.5μ ($\frac{1}{3300}$ inch) apart; in others 12μ ($\frac{1}{2100}$ inch). Some European observers give the distance as 2.5μ ($\frac{1}{10000}$ inch), but I have seen no furrows so narrow as that in our American forms. The measurements,

taken from the middle line of one ridge to the middle line of the next, have an average width of about 12μ or $\frac{1}{2000}$ inch.

On the back of this Rotifer, just below the two ciliary discs, are seven small projections arranged in three rows, two in the first, three in the second, two in the third. They are easily found by the $\frac{1}{4}$ or $\frac{1}{5}$-inch objective, provided the animal is in the proper position. When once recognized they may be almost as readily seen with the $\frac{2}{3}$-inch. They are absent from *Limnias ceratophylli.* The reader may perhaps discover their use. Nobody else has been able to do so.

I have had two annulated tubes of this species on the slide at the same time, each containing six eggs.

7. Megalótrocha (Fig. 160)

The clusters formed by *Megalótrocha* are not rarely so large that they become visible to the naked eye as little whitish masses clinging to the leaflets of *Myriophyllum,* which they seem to prefer. With the pocket-lens the individual Rotifers may be seen rising and bobbing about as they expand or contract, but a low power of the compound microscope is needed to appreciate their beauty.

Fig. 160.—Megalótrocha.

The expanded body is somewhat trumpet-shaped, soft and flexible, and when young colorless, becoming slightly yellowish as it increases in age.

The ciliary disc (the corona) is kidney-shaped, and placed somewhat obliquely.

In a single row across the breast, are four, rounded, somewhat roughened elevations, or large warts, that are characteristic of this Rotifer. They are rather difficult to find at the first attempt, but when seen they tell, without a possibility of doubt, that the specimen belongs to this genus. What use they may have cannot be even guessed; they may be intended only for ornament. Nobody knows.

There is but one known species (*M. alboflávicans*) in this

country and in Europe. In Queensland, Eastern Australia, another species has been discovered with only two opaque warts, one on each shoulder.

The eggs are often to be noticed adhering to the lower part of the parent.

When the young one is hatched, it either remains in the old colony to increase the size of the cluster, or it takes its departure, and founds a new group. In favorite localities, colonies of almost any number of members may be obtained.

The Rotifers of old colonial clusters are often infested by an infusorial parasite, that runs over the surface, and apparently feeds on the mucous matters secreted by the Rotifers' skin. It is called *Chílodon megalótrochæ*, and resembles, in a general way, the *Chilodon* shown by Fig. 128.

8. Conochílus (Fig. 161)

In the writer's locality free-swimming colonies of *Conochílus vólvox* are among the Rotifera most frequently met with, especially in the spring of the year, at which time they seem most numerous and, like many other denizens of the ponds, then have all their functions exceedingly active.

Fig. 161.—Conochílus.

The rounded, freely floating colonies are visible to the naked eye as they roll through the water, especially if the vessel containing them be held against the light.

Each Rotifer inhabits a gelatinous tube of her own secretion, but these sheaths are so closely pressed together that they soon become confluent, or coherent, and the jelly-mass then seems to be common property. This is especially true with the older and larger colonies, which are formed by the pretty constant addition to them of young *Conochili*, the whole cluster thus varying in age with the age of its members, and gradually but surely increasing in size, until the mass becomes so large that it breaks apart, the separated groups sailing off as if nothing unusual had occurred.

These Rotifera have their feet directed toward a common center, the bodies radiating outward, and the ciliary disc of each projecting, with a portion of the body, beyond the mucus and into the water. The ciliary disc is horseshoe-shaped.

As many as a hundred members have been seen in a single colony.

Reproduction is by means of eggs.

Notice the two large antennæ rising from the center of the ciliary disc (the corona), with their bases close together, and near the mouth, or more correctly, the "buccal funnel." Each is terminated by a bristle that can be withdrawn into the antenna as into a sheath. A similar arrangement obtains in *Melicerta*, but is there much less easily seen.

9. PHILODÍNA (FIG. 162)

This particular species is readily distinguishable from the common Rotifer (*Rôtifer vulgâris*) by the spines scattered over the back and sides of the body, which is, in addition to these thorns, roughened and ornamented by minute, hemispherical papillæ. The body is flexible, yet the skin is hardened and leathery, and carries on the animal's back several conspicuous, curved spines or thorns, that vary in number from ten to twenty. Specimens with fourteen are not rare. All but two of these, one on each side of the body, are directed backward, these two always pointing forward. Their existence has been denied by some observers, but they are always present, although they are detected with some difficulty, because they are pressed so closely against the sides of the body.

FIG. 162.—Philodina aculeáta.

Philodína has two eyes, but they are placed, not on the proboscis or frontal column, but at some distance behind the front border, while in the genus *Rotifer* they are close together on the proboscis. This position of the eyes of *Philodina*, or in what is called the cervical position, is an infallible point by

which the members of this genus may be distinguished from species of the genus *Rotifer*.

This is *Philodína aculeáta*.

The foot bears two tail-like spurs, shown in the figure projecting beyond the contracted body. They are long, tapering and pointed. The foot itself terminates in four short, unequal toes difficult to observe, as they are visible only when the animal is creeping, being quickly protruded at that time, and as quickly withdrawn.

The Rotifer's movements are slow and creeping. It seldom swims. The animal is large, heavy in appearance. It is not uncommon. The writer has captured it in summer, and has taken it from under the ice in February. Its color is usually some shade of brown.

The jaws are coarsely striated, and each, in addition to the striæ bears three large, microscopically massive, diverging teeth.

10. Rótifer vulgáris (Fig. 163)

This is the commonest of all the Rotifera. Hardly a drop of water from the proper localities comes to the microscope-stage without bringing with it one or more of this abundant and cosmopolitan species. It is usually one of the first animals to attract the attention of the microscopist, at his earliest attempt to investigate the life within the nearest pond or ditch, and to the end remains almost a constant companion.

Fig. 163.—Rótifer.

The whitish body is long and spindle-shaped, and tapers from near the middle to both extremities when the two anterior ciliary discs are unfolded.

Ever since the animal was described by Ehrenberg in 1838, until within a few years past, it has been described as having only two toes, whereas it has three; they are small but distinctly three in number. That there are two is one of the many statements of microscopical observations that have been accepted as correct, on the dictum of some acknowledged

authority, who worked many years ago, and with objectives immensely inferior to even the cheapest and lowest grade lenses now at our disposal. *Rótifer vulgáris* has three toes at the extremity of a long foot that is jointed, and that, by means of these telescopic joints, can be entirely retracted into the body.

Between the two ciliary lobes is a narrow, cylindrical projection, ciliated at the truncated tip, and nearly always bearing two little red eye-spots close together. This is the proboscis, or frontal column.

When hungry, *Rótifer* clings to the slide by her three toes, expands the ciliary discs, and sends a food-bearing current through the preoral passage to the true mouth, the mastax. When desirous of changing her locality, she may either loosen her hold by the tips of her toes, and be carried through the water by the action of the frontal cilia, or she may fold the ciliary lobes together, and go looping about by clinging with the tip of the proboscis while she draws up the foot, when, fastening it to a new place, she lets go with the proboscis, extends the body, takes a new hold with the foot, and thus moves forward rapidly, somewhat with the movement of the "measuring-worm."

Rótifer vulgáris produces her young alive, and in that connection is a problem that the reader has an opportunity to solve, or try to solve. It is, that although the living young has been seen to leave the parent's body through the posterior intestinal region, the cloaca, it is not known how those young pass from their free position in the mother's body-cavity, to the cloaca, whence they have been seen to issue into the surrounding water.

Dr. C. T. Hudson, writing on this subject in his monograph on the Rotifera, says it is possible that the long thread, which is often seen to pass from the posterior end of the ovary toward the cloaca, may really be, not a muscle, as is usually supposed, but the collapsed oviduct terminating in the cloaca. Should this be the case, then the ovum, when it drops from the ovary does not fall into the body cavity, as has been supposed, but simply stretches out over itself that portion of the delicate

investing membrane, which had, up to that moment, been shrivelled into a mere cord. As the membrane investing the ovary is of extreme tenuity, it is just possible that it has escaped observation when extended, not only over the ovary, but over even the developed young. And Mr. C. F. Cox, who has made a special study of the subject, says that the ovarian sac opens into the cloaca, near the contractile vesicle. This is a little problem in microscopical anatomy that the reader may consider, and solve if he can.

Another interesting fact is, that although *Rotifer vulgaris* is common everywhere, and has been studied in thousands of specimens by many practiced observers in every civilized country on the globe, during the century and a half that has elapsed since the animal was discovered, the male *Rotifer vulgaris* has never been seen.

11. Stéphanops (Fig. 164)

There are several species of these pretty little Rotifers. All of them may be known as members of this genus by the extension of the front of the lorica over the ciliary disc, like the visor of a boy's cap. A not uncommon species is shown by Fig. 164, in side view, so as to exhibit the long bristle springing from the back, and the curved visor which, in the figure, looks like a hook above the coronal cilia, yet is, in front view, a circular shield.

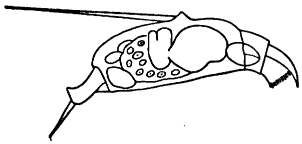


Fig. 164.—Stéphanops.

This Rotifer is one of the nibblers. The mastax is protruded from the preoral aperture, near the front of the lower flattened surface, and bites and tears the food with which it meets. The animal is often seen gliding over aquatic plants, nibbling as it goes.

The lorica is thin and somewhat flexible; it extends over the sides of the body, so as to give the Rotifer an ovate outline when seen from above or from below. The bristle on the back is movable and flexible.

In another species (*St. lamellâris*), the lorica is prolonged at the posterior border into two lateral teeth. In another (*St. mûticus*), this part is without teeth, and the dorsal bristle (seta, or slender spine) is also absent, as it is from all known American species, except the one shown in FIG. 164. *St. muticus* is not uncommon. *St. unisetâtus*, the species here figured, is frequently found among the weeds.

Species of Stêphanops.

a. Lorica without dorsal seta (*b*).
a. Lorica with dorsal seta, *unisetâtus.*
b. Lorica ending behind without spines or points, cylindric, *mûticus.*
b. Lorica ending behind in 3 spines or points; foot with one spine, *lamellâris.*

12. PTERODÍNA (FIG. 165)

The lorica is almost circular, much flattened, and perfectly transparent.

The anterior border has a broad notch with rounded margins, over which extends a lip with a central rounded projection.

FIG. 165.—Pterodína pâtina.

The ciliary discs are two, and rather widely separated.

There are usually two red eye-spots.

The foot is long, tail-like, exceedingly flexible, and so wrinkled transversely that it appears to be formed of narrow rings. It can be withdrawn entirely into the lorica, and the Rotifer seems to take pleasure in so withdrawing it. The foot has no tail, but is terminated by a small sucker bordered by a ring of fine cilia.

The Rotifer is often seen among the leaflets of *Myriophyllum* and other aquatic plants. It is *Pterodína pâtina.*

Notice the two long, slender muscles, one on each side of the animal and extending obliquely outward, from the back of the head to the attachment to the lorica. Each is rather coarsely striated transversely, with striations somewhat similar to those of the voluntary muscles of other animals, but coarser and more conspicuous. Each is pretty constantly in action, especially when the *Pterodína* is quiet. As the head, bearing the frontal cilia and other appendages, is withdrawn into the lorica, each of these muscles swings to one side in a gentle curve, and again straightens out and becomes tense as the head is allowed to protrude from the front. Their structure and their action are worth noting. They are shown imperfectly in FIG. 165.

Hudson and Gosse, in their manual of "The Rotifera; or Wheel-animalcules," in reference to *Pterodína* say, "The contractile vesicle appears to be absent," and Dr. Hudson, writing of this particular species says, "I could see no trace of a contractile vesicle," yet this organ is present, and can be detected by careful scrutiny. It is difficult to find, as it is small and usually concealed by the contents of the stomach and of the intestine.

13. SCARÍDIUM (FIG. 166)

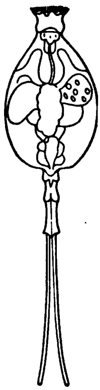


FIG. 166.—Scaridium.

The transparent, glassy lorica is rather squarely vase-shaped, somewhat flattened, and generally has a tooth-like projection on each side of the posterior border.

The Rotifer can always be recognized by its two long toes.

The foot is formed of two joints slightly enlarged at the ends.

The Rotifer is not very common, nor yet very rare.

14. POLYÁRTHRA (FIG. 167)

The contour of the lorica is somewhat like that of an egg, with both ends cut squarely off. The character, however, by which the Rotifer may always be known, is the presence of the twelve long, serrated, oar-like

appendages that project backward from the front part of the upper and the lower surfaces, from near what may perhaps be called the shoulders.

These are arranged in clusters of three each, one group being on each side below, and one on each side above. Only six are shown in the figure. By them the Rotifer makes long, quick, sudden leaps, often jumping so rapidly that it can hardly be seen; it appears to spread the appendages and to vanish. Occasionally it turns a complete somersault.

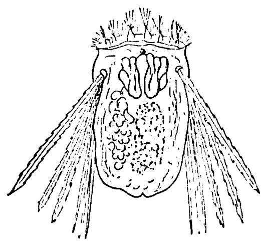


FIG. 167.—Polyárthra.

The cilia are arranged in a row along the front border.

There is no foot.

The mastax is pear-shaped and large, but its structure is difficult to make out.

The Rotifer has only one eye, which appears to be near the center of the upper front surface.

The little creature has been called by some writers, the "sword-bearer," and is said to be common in certain localities, but the writer has never been fortunate enough to find it in the waters near his home. It is not rare in New York, and in the southern part of New Jersey.

15. BRACHIÓNUS (FIG. 168)

There are numerous species of this genus, all of which may be known by the presence of a lorica with several tooth-like projections, or long spines, on the front margin, and often likewise at the rear; by the two ciliary discs and, when present, the single eye-spot.

The species whose empty lorica is shown in FIG. 168, is attractive in its glass-like transparency, active movements, and beautiful lorica. It is not uncommon. It may be easily recognized by the ten long teeth or spines on the front border—the central one on the upper side or back is the largest, and is bent usually at a right angle—and by the four posterior spines.

The foot is long, narrow, and has two toes.

Eggs are occasionally to be noticed attached to the posterior margin of the lorica. It is *Brachiónus militáris.*

The surfaces of the lorica are tessellated, or marked in polygonal areas, and covered by small raised points, all of which add much to its beauty and its interest.

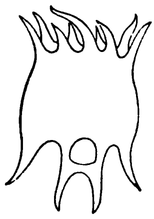


FIG. 168.—Brachiónus; an empty lorica.

The only work on the Rotifera in the English language is Hudson and Gosse's "The Rotifera; or Wheel-Animalcules," published in London, in two volumes with a supplement, 4to, a valuable monograph, that every student of microscopic pond-life should possess, although it does not deal extensively with American species.

The "Wheel-Animalcules" of this country form an extensive field for scientific research that should be cultivated. There is room here for many discoveries, and likewise an opportunity to add greatly to the world's store of scientific information.

In the "Bulletin of the United States Fish Commission," Vol. XIX, 1899, Professor H. S. Jennings has published "A List of all Rotatoria hitherto found in the United States, and the localities where they have been observed." This is a valuable and useful paper for reference.

In the Bulletin of the same Commission for 1902, Professor Jennings has issued an important "Monograph of the Rattulidæ," a Family group of the Rotifera; and the same author has in *The American Naturalist*, Vol. XXXV, Sept., 1901, published a Synopsis (or Key) of the Rotatoria, with the characters of the Classes, Sub-classes, and Orders.

In *The American Monthly Microscopical Journal*, for May, 1902, an anonymous writer has issued "A Key to the Rotifera," that the reader will find particularly useful, and especially adapted to his needs.

CHAPTER IX

FRESH-WATER POLYZOA

THE reader now approaches a group of microscopic animals whose beauty is so exquisite, so delicate, so refined in its comeliness and grace, that no description could be too extravagant, no rhetoric too fervid when applied to the charming little creatures. Yet most of this fairness seems wasted, so far as human appreciation is concerned, for how few among the millions of human beings in all the land know, or care to know, what the *Polyzoa* are, or how they look, or where they live, or whether they live at all?

Nature was never in better mood than when she began the development of the *Polyzoa*. She fashioned them with care, and placed them abundantly in our slow streams and shallow ponds, where they live and die and melt away in the shade of the lily-leaves, where no human eye sees their loveliness, until a wandering lover of Nature spies them and is happy.

The word *Polyzoa*, formed of two Greek words meaning "many animals," refers to their habit of living in colonies, that sometimes reach an enormous size. These clusters are, with but one exception, always adherent to some submerged object, except immediately after leaving the egg, when the young animals lead a short, free-swimming life. When once attached they are adherent till death.

The animals themselves are small, but often apparent to a trained eye; they are always visible under a good pocket-lens. The colonies, however, of the fresh-water forms need no magnifying; some of them are even conspicuous. These communities are formed of the protective coverings or sheaths secreted by the animals. Some take the form of narrow, brownish tubes, adherent to the lower surface of floating chips, boards,

waterlogged sticks, or even occasionally of lily-leaves or the submerged stems of grasses.

The little tubes branch like miniature trees, and spread over the surface to which they adhere as if the delicate tree had been flattened down, and pressed so hard that it could never again rise up; or they may be attached by the base only, the trunk and the branches then floating and waving in the water.

The animals secreting these tubes live in them, projecting a part of the body beyond the orifice, and quickly retreating when frightened. They are usually exceedingly timid, retiring into the tubular home at a slight disturbance of the water, needing a long time in which to recover and again to look out at the entrance, there to spread their beautiful tentacles.

In other forms the colony is surrounded by a thick, rather firm, jelly-like material, from which the animals protrude themselves, and into which they retreat. These jelly masses are usually colorless and semi-transparent, or they may be tinged a pale red. They are to be found in the purest of still water, adhering to sticks, capping a submerged stump with a cushion of living jelly, clinging like crystalline globules to any projecting rootlet or water-soaked object beneath the surface, even to smooth stones. In bulk they may be like a boy's marble, or a cart-wheel, with every intermediate size. They vary so much that to find a good comparison is not easy, and it is only right to say, lest some lover of these lovely creatures should be envious, that a colony the size of a cart-wheel has, in the writer's locality, been found but once, the foundation of this remarkable growth probably being the rim of a discarded old wheel that had been thrown into the water.

When the tubular or the jelly-like colonies are removed to the collecting-bottle, they appear lifeless and unattractive. The jelly-mass may excite wonder by its size, or curiosity to know what it may be, yet otherwise it will not be noticeable. But wait a while. Place the bottle in the shade and wait for a few minutes; with a pocket-lens look at the surface of the jelly, or at the tips of the branching tubes. Treat them with care; move them gently. The little creatures are easily

frightened, and like a flash leap back into their protective case. Perhaps while you gaze at the reddish jelly, a pink little projection appears within the field of your lens, slowly lengthens and broadens, retreating and reappearing it may be many times, but finally, after much hesitation, seeming suddenly to burst into bloom. A narrow body, so deeply red that it is often almost crimson, lifts above the jelly a crescentic disc, ornamented with two rows of long tentacles that seem as fine as hairs. They glisten and sparkle like lines of crystal, as they wave and float and twist the delicate threads beneath your wondering gaze. While you scarcely breathe, for fear the lovely vision will fade, another and another spreads its disc and waves its silvery tentacles, until the whole surface of that ugly jelly-mass blooms like a garden in Paradise—blooms not with motionless perianths, but with living animals, the most exquisite that God has allowed to develop in our sweet waters. Perhaps you make an inarticulate cry to your companion, who is probably wondering why you are so still, and what you are doing on the ground with the lens so close to the bottle, and as he too gets down and brings his lens to bear, maybe he jars the water, and the lovely *Polyzoa* flash their tentacles together and dart backward into the mass, leaving it as indescribably ugly as before. If he take you to task, tell him to wait and look. And while he looks, the little bodies again slip outward, the crescentic discs again spread open, the shining tentacles unfold and curl and lash the water, until once more the ugly jelly mass becomes a thing of indescribable beauty. This is *Pectinatĕlla,* well named the magnificent.

The jelly is formed by the animals, and is in reality a collection of protective loricæ; the huge masses often found are the result of the increase in the numbers of the *Polyzoa* inhabiting them; or, as must frequently occur where they are abundant, of the union of several contiguous growing colonies.

A single animal begins the cluster; it becomes two by a process of budding, the bud finally becoming another Polyzoön, secreting more jelly, budding in its turn, until the community

may in the end contain numberless members, and the mass may measure several feet in diameter.

The color of the animals is usually a pale red or flesh tint, deepening to crimson about the mouth near the center of the crescentic or horseshoe-shaped disc of tentacles. In the largest, and therefore the oldest colonies, the jelly may exhibit many scattered white spots composed of the carbonate of lime.

There is another jelly-forming colony, *Cristatélla*, which the observer may mistake for a young *Pectinatélla*. It is to be distinguished by the absence of those great masses which characterize *Pectinatélla*, by the general appearance of the colony, and by its motion. A community of Cristatélla is usually long and narrow, often measuring several inches in length. One species is about eight inches long, ¼ of an inch wide, and ⅛ thick. Young colonies are smaller, and are rounded. It has the power which no other fresh-water Polyzoön possesses, to travel from place to place, yet it moves slowly, a colony about an inch in length traveling an inch in twenty-four hours.

All the fresh-water *Polyzoa*, of which there are several genera and species, have on the front part of the body a disc which bears the tentacles. It is named the lophophore, and is, in some forms, horseshoe-shaped, in others nearly circular. The tentacles are arranged on it as on a base, usually in a double row. The word means "wearing a crest."

In those *Polyzoa* which secrete hardened, tubular, tree-like sheaths on the surface of submerged objects, the lophophore is protruded from the orifice in the end of the branch, much as in *Pectinatella*, and there is only one animal to each limb or hollow twig. The protrusion and expansion of the lophophore can be seen with a pocket-lens, as in FIG. 169 (from Professor Alpheus Hyatt's work on the *Polyzoa*), when it resembles in from that of *Pectinatella*. Those inhabiting the tubular sheaths seem much more timid than those in the gelatinous forms, retreating on slighter provocation, and remaining longer before they reappear and again spread the lophophore and the tentacles. They are as graceful and as attractive, perhaps they

are more so, since they seem more delicate and less able to protect themselves.

The tentacles are finely ciliated, as the microscope will show. The currents produced by the active vibrations of the cilia on the sixty to eighty tentacles of *Pectinatella*, or the eighteen to twenty in other members of the group, are powerful, and, setting in toward the center of the lophophore, sweep the entrapped food to the mouth.

The body of the Polyzoön is a transparent, membranous sack, with the lophophore and the mouth at the free end, most of the rest being immersed in the jelly, or concealed in the brown opaque sheath.

The mouth has on one border a short tongue-like organ, which can close the opening and prevent the escape of the food. Extending from the mouth to the stomach, is the food-passage or œsophagus.

The stomach itself is a widened tube, usually conspicuous on account of its contents, and the alternate, narrow, reddish-brown and yellow bands that traverse it lengthwise. It is suspended in the hollow body, and is bathed by a colorless fluid that fills the body-cavity, and extends also into the hollow tentacles. The stomach is followed by the tubular intestine, which curves forward, and generally opens below and on the outside of the lophophore.

The animals have no heart and no blood, unless the liquid in the space between the outer wall of the stomach and the inner wall of the body may be said to be blood.

When the animal is frightened, the sides of the lophophore close together, the tentacles collect themselves into a bundle, and the front of the Polyzoön is drawn back into the body, a muscle around the border then closing that opening. The jelly of *Pectinatella*, and the hardened tubes of the other forms, are the protectors of the body, while the body receives and encloses the lophophore and the tentacles, which are thus doubly protected. When the danger is past, the tips of the bundle of tentacles are cautiously pushed into the water, the lophophore follows, and if the creature's confidence is restored, the

crowns are spread open in all their indescribable grace and beauty.

The favorite food consists of small Algæ and Infusoria, which the ciliary currents sweep toward the mouth, the tentacles forming a cage from which the most active little animals seldom escape, unless the captor is willing. The tentacles are used not only to capture the food, but "for a multitude of other offices. They are each capable of independent motion, and may be twisted or turned in any direction; bending inward, they take up and discard objectionable matter, or push down into the stomach and clear the œsophagus of food too small to be acted on by the parietal muscles."

To examine the *Polyzoa* under the microscope demands a deep cell to hold a large quantity of water, and to prevent the cover-glass from pressing on the bodies. It is often better to place the microscope in an upright position and to omit the thin cover. In this arrangement the water trembles easily, and not only interferes with the distinctness of the image, but terrifies the timid creatures on the slide. The observer must be careful not to touch the table, and to make his examination in a quiet room. The charming creatures will ask a little attention and some gentle treatment, but what they will show with the help of a one-inch objective will amply repay the student for all the outlay of time and patience.

The following Key to the genera will help the student to name the forms that he may find.

Key to Genera of Fresh-water Polyzoa

1. In a jelly-mass (*a*).
2. In adherent, branching, cylindrical tubes (*b*).
3. In adherent, branching colonies formed of tubular, club-shaped cells (*c*).
4. In attached, pendant stems formed of urn-shaped cells (*d*).

   a. Jelly-mass rounded, adherent, often very large. *Pectinatĕlla*, 1.

   a. Jelly-mass long, narrow, slowly traveling. *Cristatĕlla*, 2.

a. Jelly-mass small, sacciform, finally lobed or branched. (Very rare). *Lóphopus*, 3.

b. Lophophore horseshoe-shaped. *Plumatélla*, 4.

b. Lophophore circular. *Fredericélla*, 5.

c. Lophophore circular; tentacles in a single row. *Paludicélla*, 6.

d. Lophophore circular or oval; tentacles in a single row. *Urnatélla*, 7.

1. Pectinatélla magnífica (Fig. 169)

The appearance to the naked eye of the colorless jelly-like substance surrounding the bodies, and of the animals themselves, has already been referred to on a preceding page.

Pectinatélla is not sensitive to sound, but a jar, or a shock to the water, sends the animals into their contracted state with surprising suddenness.

The colonies are numerous throughout the summer and until October. They are most frequently found in the shade, although they may live in the sun if they are below the water. Exposure to air and sunlight together is speedily fatal. Transfer the jelly to the collecting-bottle as soon as possible, otherwise you will have, on your return home, nothing but a softening, slimy mass that you will soon be forced to throw away. If suspended in a large vessel of water kept fresh by frequent change, *Pectinatella* will live for some time in captivity. In Fig. 169 (after Hyatt) is shown a small colony with the lophophores and tentacles expanded and enlarged, as they appear with a good pocket-lens. The absence of color and motion, however, makes a great difference in their beauty.

Fig. 169.—Pectinatélla magnífica.

In old colonies, especially late in the season, there are often to be seen many small, rounded, brown bodies, that, as the animals die, float to the surface of the water. These are the winter eggs or statoblasts. They are formed within the

body, and escape only after the Polyzoön dies and melts away, when they float out, and remain unchanged until the warmth of spring develops them.

Under the microscope, the statoblasts of *Pectinatella* are seen to be encircled by a row of double hooks, as shown in FIG. 176. The writer has collected them late in the autumn, and, keeping them in a small aquarium in a warm room has had them hatch out in November. The young fastened themselves to the sides of the glass bowl, where they appeared like delicate grains of translucent pearl. There was no jelly at this early stage, and each little *Pectinatella* stood alone, consequently all the internal organs were even more distinctly visible than usual, through their hyaline bodies. The author hoped to see them develop into colonies, but the surroundings were not entirely favorable, perhaps the proper food was not attainable and they died.

Each mature Polyzoan has from fifty to eighty tentacles.

2. CRISTATÉLLA

The form and movements of *Cristatélla* have already been referred to on a preceding page. The young colonies are rounded, and are found in the same localities as *Pectinatella*.

The statoblasts are circular, and have two rows of double hooks, one row around the border, the other nearer the center (FIG. 177). The hooks are not simple as are those of *Pectinatella*, but have several branches at the top of the stem, and the tips are forked.

According to the writer's experience *Cristatella* is not common.

3. LÓPHOPUS

A species of *Lóphopus* has been found in California, and the same form has been obtained by the writer in a small pond on the Pennsylvania side of the Delaware River, opposite Trenton, N. J. It has not been reported elsewhere. It seems to be rare in this country. In Europe it was the first member of the *Polyzoa* to be discovered, as it was by Trembley, the famous experimenter with *Hydra*, one hundred and fifty years ago.

The only known species has been named *Lôphopus Trêmbleyi* in his honor.

The colonies form small jelly-masses attached to the rootlets of *Lemna*, to floating sticks or to other submerged objects. These little masses are slightly motile, after the manner of *Cristatella*, as affirmed by some observers and denied by others.

The masses are transparent. The attached base in the old colonies becomes opaque, while in the young it is as hyaline as the rest of the mass. The jelly-masses are at first sac-like, finally becoming lobed or even branched. The *Polyzoa* are irregularly scattered throughout the colony, extruding the horseshoe-shaped lophophore as do the other and commoner forms.

Lôphopus as a colony, varies from $\frac{1}{10}$ to $\frac{1}{8}$ inch in diameter. Each mature member of the cluster bears from fifty to sixty tentacles on its lophophore. The statoblasts are produced in two forms, both of which are shown in FIG. 175.

4. PLUMATÉLLA (FIG. 170)

The tubes containing the animals may be attached only at the base, or the whole colony may be adherent to the submerged surface on which it grows. It is to be found in shallow water usually near the shore.

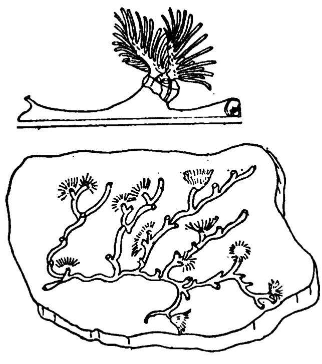


FIG. 170.—Plumatélla; colony and expanded lophophore.

To see the lophophore and the expanded tentacles, if the colony is small, the microscopist may remove it by slicing the wood to which it is attached, the slice to be placed in a watch-glass of water on the microscope stage, which should be in a horizontal position. The mirror may then be swung above the object, and *Plumatélla* viewed by reflected light as an opaque specimen.

It is exquisitely beautiful in this position, as is *Pectinatella* or any other of the Polyzoa; but the animals are timid. To see the expanded tentacles will demand much time and patience.

Plumatella is almost as common as *Pectinatella*. A board or a log that has been floating undisturbed in the pond, will, during the summer, be almost sure to afford a rich harvest of *Plumatella*, if its under surface be examined.

The statoblast of *Plumatella* is shown in FIG. 174.

5. FREDERICÉLLA

The colonies of this Polyzoön are found in the shadiest places and near the shores of shallow ponds, growing like *Plumatella*, and often in company with it, on the lower surfaces of floating or of submerged objects.

The whole colony may be adherent, or only the base, the stem and branches then floating. A single animal inhabits each hollow branch, and resembles *Plumatella* in appearance and in structure.

It may be distinguished from *Plumatella* by the oval or nearly circular lophophore. That of *Plumatella* is horseshoe-shaped.

The colonies are usually small and cover a small space.

The tentacles are never more than twenty-four in number.

The statoblasts are more or less ovate or reniform, and are without spines or hooks (FIG. 173).

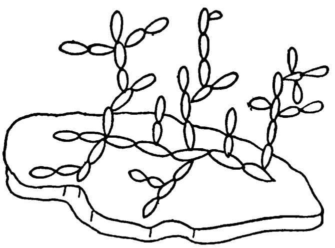


FIG. 171.—Paludicélla.

6. PALUDICÉLLA (FIG. 171)

These colonies may always be distinguished from all other tube-making *Polyzoa* by their jointed appearance. Each joint or cell is club-shaped. The colonies are irregularly branched, and are built up of a single row of cells placed end to end. The narrow end, the handle of the club, is attached to the broad end of the cell immediately behind it.

The opening through which the animal protrudes its circular lophophore is at one side of the broad end of each cell and near the top.

The base of the colony alone may be attached, or the stem may be adherent and some of the branches free, as in the figure.

7. Urnatélla (Fig. 172)

The form and appearance of this Polyzoön are so characteristic that it need never be mistaken; but while the other members of the group are usually rather conspicuous to the eye of a microscopist, *Urnatélla grácilis* must be especially searched for.

The colonies or stem-like growths that it forms are composed of urn-shaped cells, or segments, united end to end, and attached by a single disc-like enlargement to the supporting object, from which they hang suspended. The lower surface of stones, beneath which the water constantly flows, seems to be one of *Urnatella's* favorite haunts.

The stem-like colonies of urns are usually found two together pendant from the same disc of attachment, and appear somewhat like strings of beads. This is due chiefly to the alternate bands of brownish-white and black that surround each urn.

In length the stems vary from $\frac{1}{8}$ to $\frac{1}{6}$ of an inch, rarely reaching $\frac{1}{4}$. To be seen on a wet stone with the unaided vision demands a trained eye.

The cells or urns are joined end to end; the enlarged central portion of each is light-colored, while both the narrowed ends are dark or black. A single colony is seldom formed of more than a dozen urns. The stems thus built up are straight or somewhat curved, or even, on occasion, loosely coiled. At times the stem is branched, the secondary limb originating near the point of attachment of one cell with the preceding, but it soon falls off or voluntarily breaks away.

On each side of every segment of the mature stems is a small, cup-shaped projection, the two appearing almost like handles to the urns. These are supposed to be the remains of

branches or of those segments that have fallen away, and have gone to begin new colonies in another place. Each urn has at some time had two urns attached to it, one on each side. Occasionally a specimen will be found with one or more branches still adherent.

The central enlarged portion of the urns is translucent, light-colored, and often has many transverse wrinkles and transverse brown lines. It is also brown spotted, and has many little tubercles of the same color. The necks of the urns, where they are joined together to form the stems, are opaque and black.

The first or foundation segment of the growth is larger than the other members of the group, and its base expands into a broad disc, that adheres to the stone and supports the entire stem. Through the center of the whole collection of urns passes a cylindrical cord, whose purpose would seem to be to strengthen the fragile pile, and to give it the great flexibility that it possesses.

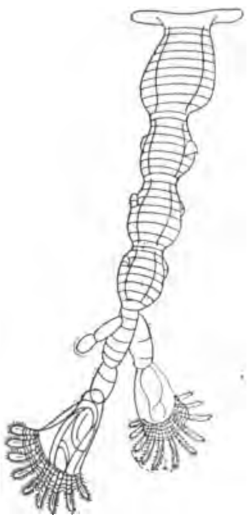


FIG. 172.—Urnatélla.

The two segments near the free end of the stem are smaller than the others, and rather different in shape. They are also more nearly transparent and colorless. They seem to be urns in the process of growth, while those above are matured and hardened.

It is only the terminal segments that contain the living animal. Those urns that form the stem above them are filled with a soft, translucent, granular substance packed into the cavity around the central cord.

The animal that produces this beautiful series of brown urns lives at the free end of the filament, solitary and alone, with the exception of the temporary companionship of those short branches that sprout out near it, as shown in FIG. 172. It is these short growths

that are supposed to drop off, and to leave the cup-shaped scars on each side. Rarely are there more than two of these projecting scars on each urn.

The animal itself, which terminates the main stem and its branches, appears when in active condition "as a bell-shaped body, with a widely expanded oval or nearly circular mouth, directed obliquely to one side or ventrally. The mouth of the bell is bordered by a broad waving band or collar, from the inside of which springs a circle of tentacles. Of these there are usually sixteen, though sometimes from twelve to fourteen. They are invested with an epithelium furnished with moderately long, active cilia."

Like most of these beautiful creatures, *Urnatella* is timid and sensitive. At the slightest disturbance the tentacles are folded together and drawn into the mouth of the bell, which closes around them, and the entire stem suddenly bows itself down to the ground, or, when long, rolls itself into a loose coil.

No eggs nor statoblasts have been observed. During the winter the urns do not seem to become separated from one another. "Perhaps, as reproductive bodies, after the polyp-bells perish, they remain in conjunction securely anchored through the first of the series, and are preserved during the cold of winter until under the favorable condition of spring, they put forth buds and branches, which, by separation and settlement elsewhere, become the foundation of new colonies."

STATOBLASTS

The winter eggs of each Polyzoan genus are characteristic; from the appearance of even a single one, if mature, its generic origin may be ascertained.

It is always a satisfaction to recognize an object when it is seen, and to be able to give a positive answer to the oft-repeated question, "What is it?" These little brown specks are sooner or later sure to bring out that question either from the observer himself or from his friends.

By means of the subjoined Key and the figures of the stato-

blasts in the text, the origin of these winter eggs may be determined. In the illustrations *A* points out the annulus.

Key to the Statoblasts of the Fresh-water Polyzoa

A. Reproduction probably by the urn-shaped segments of the stem. *Urnatélla*, FIG. 172.
A. Reproduction by statoblasts (*a*).
a. Statoblasts without spines (*b*).
a. Statoblasts with spinous margins (*d*).
b. Without a cellular annulus. *Fredericélla*, FIG. 173.
b. With a cellular, dark-brown annulus (*c*).
b. With a cellular, purplish-blue, iridescent annulus. *Paludicélla*.
c. Extremities rounded. *Plumatélla*, FIG. 174.
c. Extremities acute, sometimes prolonged. *Lóphopus*, FIG. 175.
d. Spines in a single, marginal series, double-hooked. *Pectinatélla*, FIG. 176.
d. Spines in two rows, variously hooked. *Cristatélla*, FIG. 177.

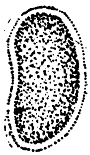


FIG. 173.—Statoblast of Fredericella.

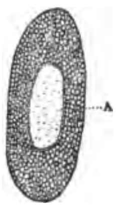


FIG. 174.—Statoblast of Plumatella.

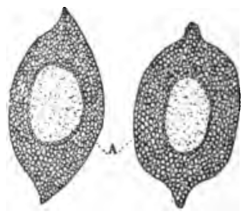


FIG. 175.—Two forms of Statoblast of Lophopus.

The writer has known the statoblasts of *Pectinatella* to be formed in so great profusion in the autumn that the surface of a pond, perhaps half an acre in extent, was as densely covered with them as the surface of the little pools along the railroad is sometimes covered with cinder-scales.

It is these statoblasts that are so often seen as dark-brown little bodies, thickly studding the surface of the half-dead

masses of *Pectinatella* jelly in September or later, and, floating on the water or entangled among Algæ or other aquatic plants, are not rarely collected by the microscopist, and come to the microscope-stage to make the observer wonder.

Although small, the largest measuring perhaps $\frac{1}{30}$ of an inch in diameter, their rich, dark-brown color makes them easily visible even to the naked eye, especially when in any abundance.

They are all oval or subcircular in outline, and much flattened, while some are bordered by one or two rows of doubly barbed hooks, whose purpose, it is supposed, may be to prevent

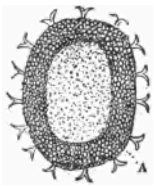


FIG. 176.—Statoblast of Pectinatella.

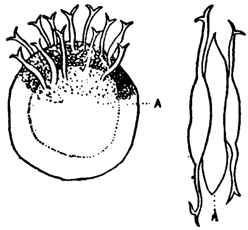


FIG. 177.—Front and side views of Statoblast of Cristatella.

the statoblast from being swept away by the currents, since the hooks form effectual anchors.

These marginal spines, or double hooks, are visible with a good pocket-lens, but on the majority of the bodies is a structure demanding the compound instrument for its elucidation. This is the annulus, a brown ring encircling the body of the statoblast, and composed of innumerable hexagonal cells. It occurs on all known forms except on those of a single genus, *Fredericella* (FIG. 173), of which the winter eggs are entirely smooth.

Within the body of each Polyzoan is a cord-like structure extending from the lower end of the stomach to the base of the cell-like posterior part of the animal. This is the funiculus, and from it the statoblasts are formed by a process of budding. "They arise," says Professor Alpheus Hyatt, "within bud-

like swellings of the funiculus, and, enlarging, slowly push out to the surface of the cord, and upward toward the stomach, until finally they hang upon the exterior, arranged alternately on either side, the youngest being at the lower end."

Each Polyzoan seems capable of producing only a limited number, yet the *Polyzoa* forming even a single colony are so numerous, that the number produced is in the aggregate astonishing. Their mode of escape, by the death of the parent, has already been mentioned.

Those that desire to be fully informed as to the anatomy of the charming creatures that form the group of the fresh-water *Polyzoa*, and to distinguish the several species, are referred to Professor Alpheus Hyatt's work on "The Polyzoa," published by the Essex Institute, Salem, Mass.

CHAPTER X

ENTOMÓSTRACA AND PHYLLÓPODA

THE reader is familiar with the crayfish, the lobster, and the crab as members of that great group of animals called the Crustacea, because they are covered by a hard, shelly coating; but, with the exception of the crayfish, he may associate them all with salt water, while in reality our fresh-water ponds are densely peopled with minute crustacean creatures.

The little fresh-water animals are often enclosed in a bivalve shell, that some of them have the power to open and to shut; or the back of the body may be simply hardened, but without a distinct shell.

The feet, or legs, are usually numerous, and hairy or bristly; in one section of those referred to in this chapter they are flattened, and each one bears near the body a flattened plate; consequently, since these parts are somewhat leaf-like, these animals have, as a class, been called the leaf-footed or the *Phyllópoda*.

Many others, to be found much more abundantly and frequently than the *Phyllópoda*, are without these plates, although the feet are as numerous and, in some, almost as flat, and the shells or shelly back as well marked. These have been, by naturalists, grouped together under the name *Entomóstraca*, the word meaning little animals in a shell, but its translation has no distinctive signification, since members of both groups are little animals and both have shells.

The *Entomóstraca* are more abundant in fresh water than the *Phyllópoda*, and are remarkably active. They are usually visible to the unaided eye as little whitish specks, skipping, flirting, or jerking themselves through the water, although probably few will measure more than one-twelfth of an inch in

length. Under the microscope some are, as already stated, seen to be enclosed in a bivalve shell, while others are entirely free from so distinct and well-marked a covering.

The feet are arranged in pairs, and may be numerous. They serve, in the shell-bearing forms, not only as swimming organs, but as gills, or similar contrivances for the absorption of air from the water for the aeration of the little animals' blood. This is probably one reason why they are kept in such incessant motion. Even when the shell-bearing *Entomostraca* come to rest, to feed, or for some other purpose, certain of the feet keep up a ceaseless beating of the water, as can be readily seen through their transparent case.

The mouth-parts are complicated; much patience and microscopical skill are needed to investigate and to understand them.

On each side of the head, and usually near the mouth, are two thread-like, jointed organs called the antennæ, and these the observer must recognize, as they often become important aids in learning the animal's place and name. They vary in length, one on each side often being short and difficult to see distinctly, while the other two are usually long and conspicuous. They are all formed of short and well-marked joints, the number varying greatly in the different genera, sometimes in different species of the same genus.

One or more black or dark-red eye-spots are commonly present. In some the eye is single, and in the center of the forehead. It may also be slightly movable at the will of its possessor. The young animal, as not rarely happens, may have two distinct eyes, that, as it grows older, become joined into one and covered by the shell.

In many forms there is in addition to the true eye, a collection of opaque matter usually situated below the eye and likely to be mistaken for it. This is the so-called "pigment fleck," which, in some *Entomóstraca*, is supposed to act to a certain degree as an eye. It is never movable, as the true eye often is, and by this immobility may be recognized. A careful examination of the true eye with a comparatively high-power objec-

tive, will reveal still further differences between it and the pigment fleck. The reader should, however, be on his guard, and not too hastily decide that the specimen has more than a single eye.

The heart is frequently visible, especially in the shell-bearing forms, being there placed at the back of the body and near the head. It beats rapidly, and apparently sends the colorless blood quickly through the system.

All these animals increase and multiply through the formation of eggs, which may remain within the shell and there be hatched, or they may be attached to the parent's body in external clusters. In the shell-bearing forms they are passed into a brood cavity at the back and between the body and the shell, where they are kept until the young are hatched, when the latter make their escape into the water, to care for themselves.

In those forms without shells, the eggs are passed out of the body into one or two small, pear-shaped sacks called external ovaries, where they remain until hatched. In these cases, however, the egg masses are carried about by the parent and become conspicuous objects. It is a common occurrence to find the little animals apparently loaded with the burden of eggs, and not uncommon to see the young escape. The "common *Cýclops*" is an instance.

No members of the *Entomostraca* are so frequently seen nor are so abundant as the *Cýclops*, and hardly any other affords so good an example of this method of depositing and caring for the eggs in external ovaries, *Cýclops* having two of the latter, while some other almost equally common forms have but one.

The external ovaries are usually long pear-shaped bodies attached, one on each side, near the posterior extremity of the animal where it narrows to form its tail-like region. The eggs are round, unless they are made polygonal by pressure, almost black, and entirely opaque. In *Canthocámptus* there is but one external ovary. Both kinds are shown in FIGS. 185 and 186.

In many instances the young, when first hatched, bear so slight a resemblance to the parent, that some of them have been described and named as entirely different animals; and it was not until they were seen to leave the egg while it was still

attached, or in the external ovary, that their true character was discovered. This is especially true of *Cyclops*, the young of which is shown in FIG. 186. It changes its skin several times before it begins to resemble its mother. A similar peculiarity is noticeable in many of the *Entomostraca.*

These little crustaceans are found in almost every body of still water. Some prefer the surface, where, on a sunshiny day, they are occasionally seen in immense numbers, sinking when a cloud shades them and rising again to the sunlight. Others are to be taken only in deep water, while still others can be obtained only at night. Many, however, are collected in every gathering of aquatic plants. They abound at all seasons of the year, even in midwinter.

Their movements are rapid and characteristic. An Entomostracan may be readily recognized as such by the unaided sight, on account of the peculiar leaping, or short, jerking motions with which it travels through the water.

They are not only interesting little creatures to the microscopist, but they are useful. They play an important part in the food-supply of fishes, forming the chief article of diet for some of our best fresh-water fish. They are almost as important as scavengers. Their favorite food is dead and decaying Algæ and animal matter, which, if allowed to remain in the great abundance in which it often exists, our ponds and slow streams would before long become putrid and unbearable. But these numerous little creatures, by eating this refuse matter, transform it into an innocent and innocuous material, and confer a benefit both on themselves and on us.

Prof. C. L. Herrick, writing on this subject, says, "Their importance depends largely on their minute size and unparalleled numbers. The majority of non-carnivorous crustaceans are so constituted that their diet is nearly confined to such floating particles of matter as are present in the water in a state of more or less fine comminution; for, nearly without prehensile organs, these animals, by means of a valvular or, at most, ladle-like labrum, dip from the current of water kept flowing by the constant motion of the branchial feet, such fragments as the snail

and scavenger-fish have disdained; bits of decaying Algæ, or the broken fragments of a disintegrated mosquito, all alike acceptable and unhesitatingly assimilated. The amount of such material that they will dispose of in a short period of time is truly astonishing."

When the shallow ponds are dried by the summer heat, the Entomostracans bury themselves in the mud, and there remain quiescent, but alive, so long as any moisture is present. When the mud is completely dried they die, but the eggs have the ability to endure heat and dryness without injury, and to develop and mature as the pools again become filled by the rain, or by the melting snow of early spring.

The *Phyllópoda* may likewise often be recognized without a microscopical examination, in this case by their large size and their almost universal habit of swimming on the back. *Branchípus*, sometimes called the "fairy shrimp," and *Artêmia*, or the "brine shrimp," are nearly an inch or more in length.

As in the *Entomostraca*, the bodies of the *Phyllópoda* may be incased in a bivalve shell or not.

The broad, flattened feet are numerous, but the branchial plates, or breathing-plates already referred to, may be small and inconspicuous, and therefore with difficulty observed by the microscopist. They are especially well-marked in *Artêmia* (FIG. 188), and in *Branchípus* (FIG. 189).

Eyes are usually present, and large. In some forms they are elevated on stalks, reminding the observer of the stalked eyes of the lobsters.

The eggs of the bivalve *Phyllopoda* are kept within a brood cavity, somewhat as in similarly incased *Entomostraca*, while in the shell-less forms they are carried about in a bottle-shaped sack at the end of the body, near the origin of the long, narrow, tail-like portion. In both kinds the young bear scarcely a remote resemblance to the adults.

In the fresh and the brackish waters of the eastern part of the country there are but few genera of the *Phyllopoda* represented, and none have yet been found in the ocean; on the western plains and among the Rocky Mountains they abound.

All these little crustaceans should be examined in a deep cell, to prevent the weight of the cover-glass from crushing their bodies. The shells and the shelly coating give them the appearance of firmness or of hardness, but they are delicate and easily injured. The large *Phyllópoda* will need an especially deep and extensive cell.

The following Key will lead to the common genera in both divisions of these attractive animals. The only trouble the observer may meet with in using it will probably be in determining whether the specimen is a Phyllopod or an Entomostracan; but as the former are visible to the naked eye, are large, and swim on the back, they may usually be determined by these appearances alone, and the name learned by the Key, if used in connection with a pocket-lens.

The two Entomostracans, *Diáptomus* and *Canthocámptus*, are separated in the Key by the number of the joints in their long antennæ. This seems to be a minute character to use in so artificial a table, but it need not be an annoyance to the reader, since the antennæ of these two common little crustaceans differ so conspicuously in size and length that the joints need not be actually counted. It will need only a glance to show which is *Canthocámptus*, with its short, rather inconspicuous antennæ, and the single egg-sack, and which is *Cýclops*, with the long antennæ and two external egg-sacks.

The beak referred to is the front part of the shell extended in a long, usually curved and pointed prolongation. It contains the eye and portions of the animal's head.

Key to Genera of Entomostraca and Phyllopoda

1. Legs with flat plates near the body; animal swimming on the back (*h*).
2. Legs without flat plates (*a*).
   - *a*. Body enclosed in a bivalve shell (*b*).
   - *a*. Body not enclosed in a shell (*g*).
   - *b*. Shell with a sharp posterior spine, or a tooth on or near the upper posterior angle (*c*).

b. Shell without a posterior spine, or with from one to four small teeth on the lower posterior angle (*d*).

c. Smooth; spine on the upper angle, or near the middle of the border. *Dáphnia*, 1.

c. Smooth, brown; spine on the lower angle. *Scapholéberis*, 2.

c. Reticulated; spine on the lower angle; antennæ large, cylindrical. *Bosmína*, 3.

c. Reticulated; spine or tooth on the upper angle; antennæ long, with two branches. *Ceriodáphnia* 4.

d. Beaked in front (*e*).

d. Not beaked; oval, both ends rounded; smooth or hairy. *Cýpris*, 5.

e. Posterior border with from one to four small teeth. *Camptocércus*, 6.

e. Posterior border without teeth (*f*).

f. Shell nearly spherical; posterior border truncate. *Chýdorus*, 7.

f. Shell not spherical; posterior border convex; antennæ small. *Alonópsis*, 8.

f. Shell not spherical; posterior border truncate; antennæ large, long and branched. *Sída*, 9.

g. Body long and narrow; antennæ long, twenty-five jointed. *Diáptomus*, 10.

g. Body long and narrow; antennæ short, from four to ten jointed; external ovary one. *Canthocámptus*, 11.

g. Body racquet (battledore) shape; with two external ovaries. *Cýclops*, 12.

h. Body enclosed in a bivalve shell (*i*).

h. Body not enclosed in a shell (*j*).

i. Shell nearly spherical, smooth. *Limnétis*, 13.

i. Shell oval or oblong, flattened; amber colored; with longitudinal lines. *Esthéria*, 14.

j. In brine pools and salt lakes; eyes black, on stalks. *Artémia*, 15.

j. In fresh water; males with large frontal appendages; females without frontal appendages, but with an external, posterior, broad, short, bottle-shaped egg-sack (*k*).

k. Frontal appendages much twisted and coiled; body slender. *Chirocéphalus*, 16.

k. Frontal appendages not twisted nor coiled; body stout. *Branchípus*, 17.

ENTOMÓSTRACA

1. Daphnia (Fig. 178)

There are several species of *Daphnia*, all of which may be known by the presence, on the posterior border, of a sharp spine, that is never on the lower angle. It varies in length in the different species. Sometimes it is nearly as long as the shell, and extends obliquely upward. It also varies in length and in position in the same species. It is longest in the young, and becomes short with age. In the species figured (*Dáphnia púlex*) it is usually on the upper angle, but not rarely as shown in the cut. From very old specimens it may be entirely absent; it is always present at some time in the animal's life.

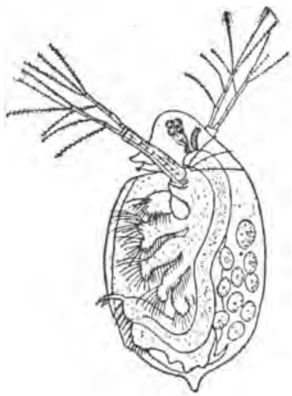


Fig. 178.—Daphnia.

The shell is oval and slightly flattened. The antennæ are prominent, and are usually divided into two parts at the free end, each division bearing several feathery bristles.

The feet are flattened, and are generally in rapid motion, so as to bring food to the mouth, and oxygen to the blood.

The heart is noticeable as a small, colorless organ under the shell of the back, and near the head. It pulsates rapidly.

The eye is large and conspicuous.

The eggs are placed in a brood cavity, as shown in the figure, and there hatched. The young differ greatly in appearance from the parent. *Daphnia* is common in the spring.

2. Scapholéberis

The shell is somewhat beaked, and in color usually dark brown. The surface may be indistinctly reticulated or entirely smooth. From *Bosmina,* for which the reader may be inclined to mistake it, the absence of the curved, cylindrical antennæ common to that species will distinguish it.

The posterior spines are short.

The eye is large and conspicuous.

The egg is carried in the brood-cavity. It is said that no more than one egg is ever present at a time.

This Entomostracan is common. With those in the writer's locality the shell is marked by a beautiful network of raised lines.

3. Bosmína (Fig. 179)

The student will have no trouble in recognizing *Bosmína,* on account of the long, large, cylindrical antennæ, each curving downward from the side of the head like the trunk of a microscopic elephant.

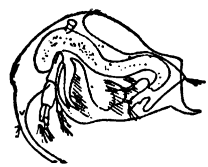


Fig. 179.—Bosmína.

The shell is oval and colorless. The posterior border bears a spine at its lower angle, never at any other point. The network of lines on the surface may extend over the entire shell, or be restricted to some one part.

The eggs are hatched in a brood-cavity on the back beneath the shell.

The heart is visible near the center of the back.

Bosmína is not so common as *Daphnia.* In my locality it is rare.

4. Ceriodáphnia

The shell of the species prevailing in the writer's locality, is, in side view, oblong or somewhat four-sided, and always beautifully reticulated in raised lines, that form hexagonal meshes somewhat irregular in shape, and unequal in size. In some specimens the lines of this network are well-developed and

at once attract attention. In others they are rather obscure and faint, but they are always present.

The head is separated from the body by a rather deep depression in the shell. Immediately behind this depression, the shell rises in a rounded elevation, beneath which is the heart that, at times, expecially when the animal's movements are restricted by the pressure of the cover-glass, is plainly visible and violently throbbing.

The eye is large, conspicuous and unusually movable. The pigment-fleck below and behind the eye is small. Sometimes it is absent.

The two antennæ resemble those of *Daphnia.* They are long, and divided each into two branches formed of three equal joints, each branch with five long bristles.

The angle or tooth on the upper corner of the posterior border is usually conspicuous and sharp. The tooth itself sometimes, not always, bears a minute, sharp-pointed tooth or prickle, that the microscopist may not perceive unless he specially looks for it.

In the microscopical aquarium this Entomostracan's movements are almost distinctive. By these movements alone it may be identified by the naked eye. It darts upward for a short distance, only to allow itself to sink back to near the starting point. Its upward progress is therefore slow and uncertain. A glass jar well stocked with these pretty little creatures leaping upward and floating back irregularly and incessantly is an attractive and interesting sight. Under the one-inch or the $\frac{2}{3}$ inch objective, the little animal is more than interesting.

5. CÝPRIS (FIG. 180)

The shell entirely surrounds the animal's body, so that the little creature, when danger threatens, shuts itself in as completely as a clam or a mussel, and falls to the bottom. Its form varies from an oval to a kidney shape, according to the species.

The color may be green, or brown, or whitish and marked with several dusky bands; the latter is our common and abun-

dant species. It may be smooth or entirely covered with fine hairs, or only the free borders may be fringed.

The shell is never opened wide. The legs and the feathery antennæ project from a narrow cleft between the valves, the little animal swimming rapidly by their aid, or creeping about the slide or over the aquatic vegetation.

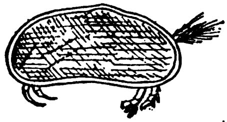


FIG. 180.—Cypris.

Cýpris is reproduced by eggs, but "the mass of eggs, including about twenty-four, is attached by the female to water-plants with the aid of a glutinous secretion, an operation which lasts about twelve hours."

6. CAMPTOCÉRCUS (FIG. 181)

The shell is elongated, somewhat quadrangular, transparent, and marked by lines traversing the surface lengthwise. The beak is blunt, and usually curved downward, or it may extend slightly away from the body. The head is strongly arched.

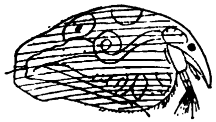


FIG. 181.—Camptocercus.

The teeth on the posterior border (not shown in the figure), are small, and vary in number from one to four.

The eye is small.

The eggs are carried in a brood cavity.

Notice the transparent heart rapidly throbbing near the middle of the back, and just below that part of the shell. It is apparently formed of two nearly equal chambers, separated by a transverse membrane. It pulsates rapidly, especially when the animal is held under the pressure of the cover-glass.

The animal occurs chiefly in lakes and in large ponds.

7. CHÝDORUS (FIG. 182)

The surface of this nearly spherical shell is usually reticulated.

The beak is long, curved and pointed; in the female it is sharply pointed.

In young specimens the posterior border is truncated, becoming more rounded in the old.

The eye is present and single.

The eggs are hatched in a brood cavity, as usual.

The animal occurs abundantly early in the spring, usually near the bottom, where it lives chiefly on vegetable matters. Its motion is rolling, and somewhat unsteady and uncertain in appearance

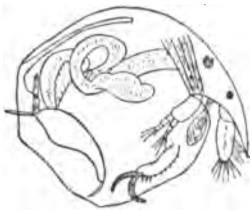


FIG. 182.—Chydorus.

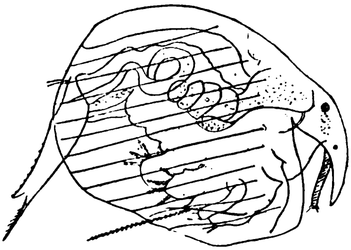


FIG. 183.—Alonópsis.

8. ALONÓPSIS (FIG. 183)

The lower or free edge of the shell is fringed with bristles that are longest in front.

The beak is long, pointed, and separated by a considerable distance from the body of the shell. The eye is large.

One of the feet, the third, bears a long spine fringed with short hairs on the edges. This spine often reaches to the posterior margin of the shell.

The surface is usually marked by a few conspicuous diagonal lines.

The animal's movements are slow.

9. SÍDA

The shell is long and narrow.

The head is separated from the body by a slight depression. The posterior margin is nearly straight, and has no spine nor tooth.

The antennæ are large and somewhat resemble those of *Daphnia*, although in *Sida* they are rather stouter, and are divided into two *unequal* branches.

There is but one species, *Sída crystállina.* It is common in some localities.

10. Diáptomus (Fig. 184)

Diáptomus may be recognized by the long antennæ, that often equal the body in length.

The stout body, including the head, is composed of six joints or segments; the posterior, narrowed or tapering region, the abdomen, of five, although in the female, two of these may be united, thus giving it a three-jointed appearance.

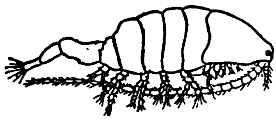


Fig. 184.—Diaptomus.

The animal is among the largest of the *Entomostraca,* frequently measuring $\frac{1}{10}$ of an inch in length.

The color is often brilliant, varying in the different species, and even in the different parts of the body of the same specimen. It may be deep red, brilliant purple, bluish with purple-tipped antennæ, whitish or even colorless.

The animals may be found in shallow pools in the autumn and early spring, and occasionally in slowly flowing streams.

The external ovary is single.

In the figure, the animal is shown with the antennæ folded under the body.

11. Canthocámptus (Fig. 185)

Before *Cyclops* and *Daphnia* this is the commonest fresh-water Entomostracan in the writer's vicinity. A gathering of aquatic plants can seldom be made in this neighborhood, without obtaining many of the graceful little *Canthocámpti.* They are visible to the unaided eye as small, flesh-colored, or pinkish lines darting through the water in short jerks, after the manner of most Entomostraca. Like all minute animals, they will collect on the best-lighted side of the bottle, where they may be easily captured with the dipping-tube.

The eye is single.

The antennæ are short and somewhat hairy.

The body is long, narrow, and sub-cylindrical, although it is widest and thickest in front.

There is no distinct functional heart.

The external ovary is single, and is attached to the parent by the thinnest and apparently most delicate filament, although considerable force is necessary to separate it from the body. The eggs are round and opaque.

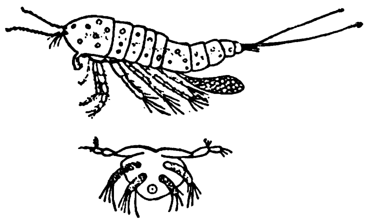


FIG. 185.—Canthocamptus.

The young differ greatly from their mature aspect, as shown in FIG. 185.

Canthocámptus is found in almost any shallow body of still water, and all the year through, even occasionally in midwinter. It is shown in side view in the figure, so as to exhibit the single external ovary so characteristic of it.

12. CÝCLOPS (FIG. 186)

This, the commonest of all the fresh-water Entomostraca, has a single eye in the middle of the forehead, like the giants of ancient story, a bifid tail adapted for swimming, and two external ovaries, one on each side. These ovaries are long, pear-shaped sacks filled by dark, opaque eggs, and are attached to the body by the narrow or stem end of the pear.

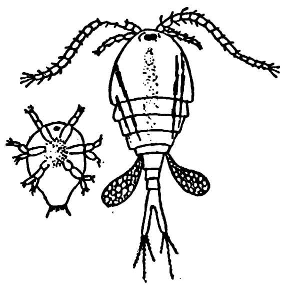


FIG. 186.—Cýclops with a young form.

The young pass through several stages before they even begin to resemble the parent.

It has been said that the eggs are carried in the external ovaries only until they are ready to hatch, when they are deposited before the young make their escape. This is a mistake, as the student will probably soon observe. The young leave the

eggs while they are still attached to the parent, breaking the egg-membrane suddenly and unexpectedly, although the observer may have been for some time watching the little creatures restlessly moving about within. At their sudden escape, they often dart half-way across the field of a low-power objective.

If *Cyclops* had no enemies, the waters would soon become filled with them in numbers beyond imagining. One female *Cyclops* has been seen to lay ten times in succession; but to be within bounds, the observer that made the calculation, supposes a single one to lay eight times only, and forty eggs each time. "At the end of one year this female would have been the progenitor of 4,442,189,120 young, that is, near four and a half thousands of millions."

There are about thirty species of *Cyclops*. On each are four antennæ, two long and conspicuous, the other two small, and often carried so that they are invisible unless the *Cyclops* is turned on the back.

PHYLLÓPODA

13. Limnétis (Fig. 187)

The oval or nearly spherical, smooth shell has a well-marked beak.

In some of the species this is enormous, while in others it is less conspicuous. When the valves are closed they measure about $\frac{1}{8}$ of an inch in length. They have not rarely been mistaken for small fresh-water mollusks of the genus *Pisidium*.

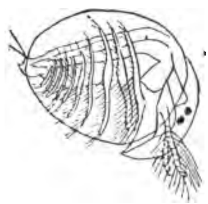


Fig. 187.—Limnetis.

The eyes are two, but so close together that they often appear to be united; they are black.

The animals swim on the back.

In the males, the two front legs are flattened, and have on the end of each a complicated organ called the hand, although it bears only the most remote resemblance to the human hand.

The eggs are carried on the back, under the shell.

The mature animals are flesh color.

14. Esthéria

The shell is smooth, shining, and marked with distinct lines running almost parallel with the front, or free edge, of the valves. It is thin, flat, and large, measuring about $\frac{2}{3}$ of an inch in length. The males have two pairs of what are called hands, or one on each of the four front legs.

The shell of the several species varies from oval to oblong, with the upper margin much flattened, or it may be somewhat globose.

Most of the species are confined to the waters west of the Mississippi River; one, however (*Esthéria Mexicána*), is found near Cincinnati. Many of them are in appearance not unlike a small clam, or the little fresh-water mollusk *Pisidium*, so common almost everywhere.

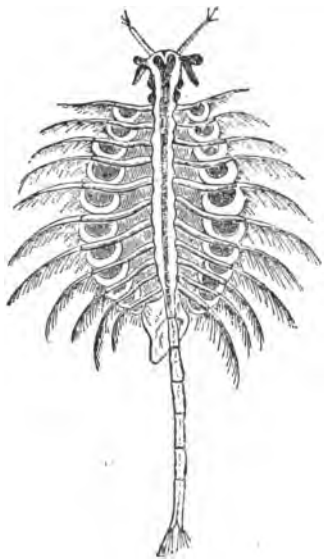


Fig. 188.—Artémia (a female).

15. Artémia (Fig. 188)

Artêmia occurs only in brine, or in the water of salt lakes. It is not rarely found in the hogsheads of water on railroad bridges or trestles, where the water is made salt to keep it from freezing.

The bodies are slender and pale red, flesh-color, or sometimes greenish.

The feet are eleven pairs beautifully fringed with many long hairs. They bear the flattened, branchial plates or breathing plates. When the creature swims on its back, as it habitually does, these feathery feet beat the water in rapid and rhythmical succes-

sion, as if a wave of motion were rapidly passing above them.

It is a beautiful creature, and one sure to attract attention, not only by its graceful motions and preference for salt water, but by its size. It is half an inch or more in length.

The eyes are black, and are placed on the ends of two stalks, one of which projects from each side of the rather small head.

The antennæ are short, but conspicuous.

The eggs are yellowish-white, and are carried in a conspicuous external egg-sack.

The young are active, and differ much in appearance from the parent. They are blood-red, with one bluish eye.

16. Chirocéphalus (Fig. 189)

This peculiar creature has eleven pairs of swimming feet, as has *Branchipus*, but there need be no difficulty in distinguishing it from *Branchipus* (for which it may be mistaken), provided the male is obtained. If the female alone is captured, some trouble may be experienced in determining the one from the other. The female of *Chirocéphalus*, however, is slender, while that of *Branchípus* is stout; but such a distinction is valueless until both have been seen, or the two sexes have been taken from the same pond.

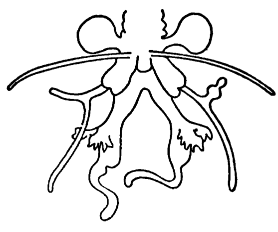


Fig. 189.—Head of male Chirocéphalus.

In the latter case, the male may be known by the two remarkable appendages that hang from the sides of the head. These are about $\frac{1}{4}$ of an inch long when extended, and are curved and coiled and twisted in a way that defies description. Each one is broad near the upper or attached end, and diminishes to a long, curved point covered with minute spines, while in its entire length it is peculiarly lobed. Fig. 189 shows an enlarged front view of the head of the male.

The egg-sack of the female is short and small; the attached

end is lengthened, somewhat like the neck of a bottle. The eggs are large, and about twelve in number.

The body of each sex is nearly $\frac{2}{3}$ of an inch in length. *Chiro-cephalus* is found in company with *Branchipus*, usually in the spring, often as early as the middle of March.

17. Branchípus (Fig. 190)

The flesh-colored or pale red body is stout and large, often measuring an inch or more in length.

The head is large; the frontal appendages of the male are long and broad, as shown enlarged in Fig. 190. These hang downward on each side of the head. They are formed of two

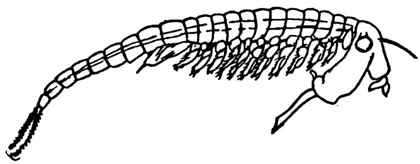


Fig. 190.—Branchipus (a male).

dissimilar parts. The upper half is broad and thick, and about $\frac{1}{5}$ of an inch in length. It ends in a stiff, bristle-like prolongation of nearly equal length, with a short, bristle-like tooth at the inner side, at the point of junction of the two parts.

There are eleven pairs of swimming feet. The animal swims on the back.

The eyes are two, black, and elevated on the ends of short stalks.

The body of the female is as large and as stout as that of the male. The egg-sack is noticeable near the point of union between the posterior narrow portion of the body, and the broader front.

It is a peculiar fact that *Branchípus* is killed by even the heat of early summer or of late spring. Dr. A. S. Packard, describing a visit to a pond where these creatures had been found on May 2nd, but from which they had all disappeared

by May 13th, says, " It seems from this quite evident that the animal probably dies off at the approach of warm weather, and does not reappear until after cool weather sets in late in the autumn, being represented in the summer by the eggs alone; and thus the appearance and disappearance of this Phýllopod is apparently determined mainly by the temperature."

A vessel full of water in which *Branchipus* is floating on its back is a strangely beautiful and interesting sight. The pale reddish or flesh-colored bodies rising and falling in long curves, with their numerous, broad feet waving together rhythmically, make a living picture long to be pleasantly remembered.

Those readers that desire to pursue the subject, especially in respect to the anatomy and the development of these crustaceans, are referred to Prof. C. L. Herrick's " Crustacea of Minnesota included in the Orders Cladocera and Copepoda," published in the twelfth annual report of the State Geologist; and to Prof. A. S. Packard's " Monograph of the Phyllopod Crustacea of North America," issued in the twelfth annual report of the United States Geological and Geographical Survey of the Territories, Dr. F. V. Hayden in charge.

CHAPTER XI

WATER-MITES AND THE WATER-BEAR

THE Water-mites (FIG. 191), of which the majority are visible to the naked eye, are sometimes called water-spiders probably because they bear some resemblance to small spiders, and have eight legs. Naturalists have seen the resemblance, and have placed them in a family group near to the spiders. Water-spider, however, is not a good name, as we have some true spiders that are semi-aquatic in their habits, and have therefore a better right to such a title.

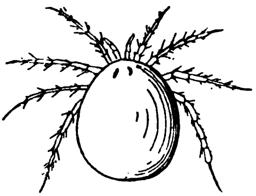


FIG. 191.—A Water-mite. Eylais.

The Water-mites are usually active little animals, swimming freely and rapidly through the water, or forcing themselves among the leaflets of aquatic plants, probably in search of food.

They may generally be obtained in some abundance by collecting water-weeds in the way previously recommended, namely, by sinking the bottle and floating the plants into it without removing them from their native element.

The animals are all usually visible to the unaided eye, and may for the most part be studied with a comparatively low-power objective.

The bodies are plump and oval, or nearly spherical. The skin of most of the forms is soft and easily broken. In the members of a single genus, *Arrenŭrus*, the surface is firm and comparatively hard.

They are all brightly, even brilliantly, colored. The surface may be of one uniform tint, with a few blackish or brownish spots on the posterior region, or the single individual may be variously tinged in different parts of the body. The colors

are of almost every imaginable shade of crimson, azure-blue, yellow, green, brown, gray, or purple. The eight long legs also share in the general brilliancy, and at times present a coloration entirely different from that of the body.

The eyes are usually on the upper surface near the front border. They are small, and may be round or crescentic in shape, and red, black, or carmine in color. They are from two to four in number, and are generally placed close together; or when four in number, they are usually arranged in two distinct pairs.

The upper part, or the back of the little animals, may be entirely smooth, densely clothed with short hairs, or with a few scattered, fine bristles. It may also present no markings when magnified, or, as in a single genus, *Arrenūrus*, may be beautifully ornamented with a network of narrow, hexagonal meshes.

In all, or nearly all the mites, the upper surface bears two or more black, dark brown or reddish spots, distinct from the general coloration of the body. These are caused by the nearness of the intestine, or of the other viscera, to the surface, the dark contents of which show their color through the skin. In some specimens these dark spots become large, and occupy much of the upper surface. These are then so arranged and formed that they leave between them, in the middle line of the body, a V-shaped space that may be white, yellow, or of some other color. These spots are called cœca or the cœcal markings, the word being the plural of cœcum, a certain part of the lower intestinal canal. They are useful to the student in identifying the species.

The lower or ventral surface is the most important part to the observer that desires to ascertain the identity of his specimen, or to the student that wishes to make a more serious study of the animal, for on this surface are the parts most used by the naturalist in classifying the mites. The observer must therefore seek to have the little creature arranged on its back before it is placed under the microscope, so that the ventral surface shall be presented to the objective.

As this is sometimes a difficult operation to accomplish without injuring the delicate body, the writer has used for the purpose a little home-made contrivance that answers well, and can be made by any one. A hole about half an inch in diameter is drilled through a glass slip, and into one side is cemented with shellac a thin-glass, circular cover, a little smaller than the hole, so that the cover may not be flush with the surface of the slip. It is not difficult to grind a hole through a thin slip, if the file or other grinding tool is kept wet with turpentine. The aperture may not be a perfect circle; it will probably be irregular, the writer knows that his is, but it will answer every purpose.

The mite is placed in this cell, and a thin cover applied to the opposite side, thus forming a glass box that can be turned over for the examination of both surfaces of the animal, and deep enough not to injure the soft body, yet shallow enough to restrain its movements.

The mouth of the mite is usually a complicated affair, and is sometimes surrounded by a circular elevation or ring called a hood; it always has short, jointed palpi, or feelers.

At some distance back of the mouth, in a few forms near the posterior border, but always in the median line, will be seen, in the female mites, a small dark spot or narrow line which is really an opening. In some species this orifice, which may be called the ventral opening, is covered and concealed by a large plate, called the ventral plate; or there may be two plates curved, oval, or of other shape, one on each side of the ventral opening. They are useful to the naturalist as one means by which the mites may be classified, and they should be carefully searched for by the observer that desires to learn the name of his specimen. They are not present in the males. The reader will therefore perceive that to identify his captive the specimen must be a female.

The two sexes differ so conspicuously in appearance that they are easily recognized. The female always has the posterior border of the body more or less evenly rounded, while the male frequently possesses a peculiar tail-like process, pro-

jecting from the middle of the posterior margin. One form of this curious projection is shown in FIG. 196, a female by FIG. 191. The projection varies in shape and size in the different species. The males seem much less abundant than the females; they are, at least, less frequently captured by the microscopical fisherman.

On the ventral surface, behind or before the ventral plates, or on both sides of them, will be observed one or more very small dark spots, never bordered by a plate. These are the external openings of the tracheæ or air-tubes, which extend through the body and supply it with oxygen. As the mites are not known to come to the surface for a supply of air, as so many other aquatic animals do, the tracheæ are supposed to be able to absorb it directly from the water. The tracheal openings are not an important aid in ascertaining the identity of the creature, but the reader must not mistake them for the aperture that is bordered or covered by the ventral plates. In some mites they are not well marked, and may be overlooked.

There is still another dark spot, usually present near the posterior part of the ventral surface, that must not be confounded with the ventral opening because it happens to be in the median line. This is the external opening of the intestine. It is never bordered by plates. It is always behind the ventral orifice, but is not always conspicuous.

Equally important to the student are certain elevations of the ventral surface that appear to cover the attached ends of the legs. These are the *coxæ*, the plural of *coxa*, a Latin word meaning the thigh. They are variously shaped and arranged, one coxa seeming to cover the end of each leg, or appearing to be the thigh belonging to that leg. They are motionless, and are really only elevations of the cuticle, beneath which the muscles of the legs may be seen in action.

In some mites the coxæ on each side of the body are arranged in groups of two each, the borders of the two that form the group being in contact either by their whole length, as in FIGS. 195, 196, and 197, or only at some single point, as in the

posterior group shown in FIG. 194. In FIGS. 194, 195, 196 and 197 there are four groups, formed of two coxæ each; in FIG. 193 there are six groups, the anterior alone being formed of two coxæ, the two posterior groups on each side being of but one coxa each and separated. Their shape differs widely, even in the species of one genus; their arrangement, however, is constant and important.

The eight legs are long and jointed. The last joint ends in one or two short claws. The hairs fringing their margins are long and numerous, and are used as aids in swimming. They add a good deal to the beauty of the animal.

Mites are found in salt-water as well as in fresh, but with the marine forms this book has nothing to do.

The fresh-water forms are propagated by means of eggs, which may often be seen attached to the stems of aquatic plants, or to the lower surface of floating leaves, where the writer has obtained them and had them to hatch in captivity. They are small, brownish, jelly-masses, that might easily be overlooked or passed by as snails' eggs that are usually to be found in similar localities.

It not rarely happens, in the temporary preparation made on the slide after a "pond hunt," that the microscopist will find a fragment of a membrane so completely and beautifully perforated by rounded openings, that he is sure to gaze at it in pleased wonderment. The apertures are irregular in size, and present no regularity of arrangement, but they are always rounded, and the resultant network is never unattractive.

On the same slide, frequently under a bit of the perforated membrane itself, are often seen one or more small colorless objects, pointed at both ends, and which, at a momentary glance, may possibly be mistaken for Diatoms. A more careful scrutiny will show that they are minute rolls of delicate and transparent membrane. With a good, high-power objective, what is called an optical section may be made, in which the optically sectioned roll will show its edges as fine, parallel lines; these lines are somewhat of a test for the objective, and for the observer's eye.

These microscopic rolls are the empty egg-membranes of one of the aquatic, microscopic mites; the perforated membrane is the covering that overarches the egg-mass to protect it from enemies, while the openings in the membrane permit the circulation of the water to keep the eggs supplied with oxygen.

The writer has found the egg-mass with its protecting, sieve-like membrane attached to *Utricularia*, and has had the satisfaction to see under it the little bundles of empty membrane, several eggs with the mites restless within and apparently eager to escape, and has had the mites hatch out of those eggs and swim actively in a watch-glass, where they were barely visible to the naked eye.

In this case the young mite is a counterpart of the older and more mature. In many other instances the newly hatched young bear but a slight resemblance to the parents, those of some genera having only six legs, while those of one species are said to have but three, a statement that seems worthy of doubt. It should probably be three pairs of legs.

Many of these immature forms are parasitic on aquatic insects, becoming free-swimming and independent only when they attain adult growth and age. Some of the mature mites are likewise parasitic in the gills of the fresh-water mussel (*Unio*). On account of these peculiarities, the study of their life-history is difficult.

Entomostraca and *Infusoria* are said to form their favorite food.

There may seem to be but little connection between the Water-mites and the Water-bear, and still less resemblance, yet naturalists have classified them near together. The Water-bear (FIG. 192) is a common and peculiar aquatic animal, so closely and so comically resembling a transparent, eight-legged, microscopic bear, that the observer will know it the first time that he sees it; further reference to it is reserved for another page.

Key to Genera of the Water-mites: Hydrachnidæ

1. Body colorless, cylindrical, elongated and transparent; legs eight, short, with claws; the animal usually walks slowly, and is remotely bear-like in appearance. Water-bear (*Macrobíotus*), 1.
2. Body brightly colored, oval or spherical; legs eight, long; animal swimming actively (*a*).
3. Body brightly colored, oval, or spherical; legs eight, long; animal walking, never swimming (*e*).
   - *a.* Ventral plate cordate, single, the apex pointing forward. *Diplodóntus*, 2.
   - *a.* Ventral plate, cordate, single, the apex rounded, pointing backward (*b*).
   - *a.* Ventral plate double (*c*).
   - *b.* Posterior coxæ on the same side not in contact. *Hydráchna*, 3.
   - *c.* Posterior coxæ on the same side in contact by their entire length (*d*).
   - *c.* Posterior coxæ on the same side in contact only by their internal ends, their outer extremities diverging. *Eyláis*, 4.
   - *d.* Ventral plates oval, with an oval plate on each side; mouth round, with a circular hood. *Arrenúrus*, 5.
   - *d.* Ventral plates narrow, curved, each with two or three transparent tubercles. *Atax*, 6.
   - *e.* Eyes four, on a lanceolate plate; coxæ in four groups. *Limnóchares*, 7.

1. The Water-bear: Macrobíotus (Fig. 192)

The body is soft, colorless and transparent.

The legs are short, and have on the end of each several sharp claws; the legs are three on each side of the body, and two at or near the posterior extremity.

The mouth is a small opening at the front of the part that represents the head. It is followed internally by two short, somewhat curved, diverging rods, said to be used to wound its prey. The so-called gizzard, at a short distance from the

mouth, is plainly visible through the transparent body. It has no motion.

Two small eyes are usually present, one on each side of the head.

The animal's movements are, as a rule, exceedingly slow and awkward. The creature when walking appears to work hard, with little result so far as progress is concerned. This may be owing to its inability to get a foothold on the hard and slippery surface of the slide.

Macrobíotus is reproduced by eggs, which are deposited in an interesting way. When they are sufficiently matured, the Water-bear sheds her skin and leaves the eggs in the empty and cast-off case. It is no unusual occurrence to find the empty skin of *Macrobíotus* with the empty eggs inside, the young having escaped. The young resemble the parent in all except size.

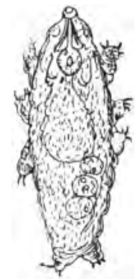


FIG. 192. — The Water-bear (Macrobíotus).

This strange bear-like creature is not rarely to be found at the bottom of shallow ponds; or, if an aquarium is kept, it will be almost sure to make the bottom its home. It is entirely invisible to the naked eye, measuring rather less than $\frac{1}{60}$ of an inch, or about 410 microns, in length.

On account of their slow movements, the Water-bears are called *Tárdigrades*.

The scientific name of the common American form is *Macrobíotus Americánus*.

2. DIPLODÓNTUS

This mite may be recognized by the form of the ventral plate as given in the Key, and by the fact that the plate is roughened by minute granules.

The eyes in one species are two in number, small and wide apart. They are on the edge of the front border. In another species they are four, and are placed so far forward on the front margin that they are best seen when the animal is on its back, and is examined from beneath.

The coxæ are in four separate groups.

The body of the two-eyed species has the front part black, spotted with red, and the posterior region red, with a central longitudinal black band. The one with four eyes has the entire body bright red.

3. Hydráchna (Fig. 193)

Fig. 193.—Coxæ of Hydráchna.

The anterior coxæ on the same side form a single group, and are in contact by their entire length; the middle coxa is entirely disconnected from the others; the most posterior is the largest.

In one species, the body is spherical and black, with yellow dots; the legs, shorter than the body, are black, with red ends. In another the body is red, with two pairs of dark-red eyes.

4. Eyläis (Figs. 191, 194)

The two anterior coxæ are in contact by their entire length and form one group on each side. The two posterior are in contact only as described in the Key, and shown in the figure. They are all moderately narrow.

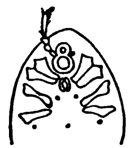


Fig. 194.—Coxæ of Eyläis.

The mouth is round, ciliated, and with a kind of hood which the observer may have some trouble to recognize.

The ventral plates are curved, almost crescentic, and narrow; one is on each side of the ventral opening; just behind them are two small tracheal apertures.

The intestinal orifice is visible at the rear, in the middle line, with a tracheal opening on each side.

The eyes are four, in two pairs, rather close together.

A large, red, nearly spherical *Eyläis* is common in our ponds.

The young are described as being red, transparent, with four eyes wide apart, and six legs.

5. ARRENÚRUS (FIGS. 195, 196)

The coxæ form two groups on each side, the two anterior being in contact by their entire length, as are also the two posterior. Occasionally the anterior groups on opposite sides are in contact at the median line, as in FIG. 195.

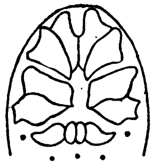


FIG. 195.—Coxæ of Arrenúrus (female).

The ventral plates are oval, their greatest length generally being from before backward; they are usually close together. The two oval, lateral plates are oval from side to side, and are sometimes curved.

The mouth is small, round, and encircled by a ring-like hood.

The skin is usually hard and roughened or covered by a deep network of strongly elevated lines, that give it a beautiful appearance. It is sometimes shed in captivity, and is not rarely found as a torn, empty, and colorless net, well worth examining with a high power. There are some soft-bodied species but they do not appear to be common.

The body of both the male and the female is truncated at the posterior border, but the male has a peculiar, short prolongation projecting from the center of that margin, as in FIG. 196, the shape of the part varying greatly in the different species. The females are the most numerous and most frequently met.

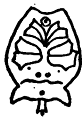


FIG. 196.—Coxæ of Arrenúrus (male).

The upper surface or back of both sexes often bears a deep, depressed furrow, sometimes enclosing a small circular or oval area confined to the posterior extremity, sometimes a large space, including the greater part of the entire back. From others this may be absent.

The eyes are two, black, and separated.

The color of the body varies greatly in the numerous species. It may be blue, green, yellow, red, or of almost any bright tint, and may be either diffused or confined to distinct parts. Thus in one female *Arrenúrus* the center of the body is brown, the sides are blue, and the coxæ yellow. In another the body is

red, the coxæ vermilion. Another, a male, has a bright yellow tail, the center of the body is white, with a blue line near the posterior border, and dark-brown cœca.

A species of *Arrenûrus* with a hard and reticulated surface, is not uncommonly captured among *Ceratophyllum* and *Myriophyllum* in rather shady places, which, the writer thinks, all the Water-mites prefer. So sensitive is it to the heat and to the direct light, that even a moment's exposure to the sunlight out of the water is fatal.

6. Átax (Fig. 197)

The anterior coxæ are in contact by their entire length; the posterior extremities of the two anterior groups on each side are also often in contact and thus appear to compress the mouth between them. The posterior coxæ are also in contact for their entire length, but they do not touch those of the opposite side of the body, they do not meet in the median line. The fourth coxa, or the one belonging to the most posterior leg, is usually much larger and broader than any of the others.

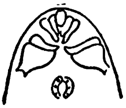


Fig. 197.—Coxæ of Atax.

The two ventral plates are narrow and curved; the tubercles on each of them are rounded and translucent.

The front pair of legs are long and curved. The hairs that clothe them are bristle-like. When the mite walks, these legs are held rigidly in front.

The color of the body varies, as it does in the other forms. A yellow *Atax* is not uncommon in our ponds, and shallow, slowly flowing streams.

7. Limnóchares (Fig. 198)

This small mite may be recognized by one invariable habit; it always walks. It never swims. In this it differs from all other known forms of fresh-water Hydrachnidæ.

The eyes are four, and are arranged on a lanceolate plate (Fig. 198, much enlarged), two on each side, with a central rounded projection between them in front. They are surrounded by hairs.

The coxæ do not make the prominent elevations common to other mites, but seem rather to be beneath the cuticle. "The coxæ of the anterior two pairs of legs are closely approximate, as are also those of the two posterior pairs, but the two groups are widely separated." The anterior are larger than the posterior. The mites themselves are small.

If the observer should desire to make permanently mounted slides of his specimens of mites, he may try a preservative medium prepared by mixing eight parts of water, containing a drop or two of carbolic acid, with one part of glycerine. This is said to keep the bodies without the loss of their characteristic plumpness, or of much of their color, if mounted in a deep cell. Two specimens should, if possible, be preserved in the same mount, and so arranged as to show the upper surface of the one, the lower of the other. They will usually need a large and deep ring for a cell-wall.

FIG. 198.—Eye-plate of Limnóchares.

The fresh-water mites have never been systematically studied by any American naturalist; there are, therefore, no books to which the reader may be referred for further aid. The field is almost entirely unexplored, so far as the Water-mites of this country are concerned. To a student with an eye sensitive to color, and with a large amount of patience, the subject should be attractive.

We possess no complete knowledge of even the commonest objects that we tread under foot in our daily movements. A little back yard "as big as a pocket handkerchief" is replete with objects about which we have no thorough information. The life-history of the commonest insect that scurries through the grass at our approach is an unworked mine of scientific riches awaiting the coming of the microscopist.

The use of the microscope by the amateur may, by some, be classed among the amusements, but it is one of those harmless amusements that may be followed by valuable results, not only to the microscopist himself, but to the world. Amateur microscopists have made discoveries, and will again make

discoveries. Professor Huxley, in one of his presidential addresses before a scientific society, speaking of the members' use of the microscope, says: "No doubt one might say that a very large result of this activity is simple amusement; but I happen to be one of those people . . . who think that amusement is an exceedingly good thing; and I am strongly disposed to think the beneficial effects of such amusements as do no harm to a man himself, nor in any way rob his neighbor, especially such as are found in microscopical studies, . . . are very great, and that they are much to be cherished as an important part of the good of human life."

The microscopist "is dealing with natural objects, and every new thing observed, every fresh beauty discovered, is something added to the stock of natural knowledge. . . . There is not a single genus or species of which we may say that we know the whole history. The common *Paramæcium*, for instance, is one of the commonest things that exists, yet nobody certainly knows whether it has any other mode of reproduction except by fission, . . . and it is a perfect opprobrium to science that nobody known what an *Amœba* is. I do not mean to say that we do not know the things we call by that name when we see them, but that we are unable to say with certainty what are their modes of reproduction, what are their various states, which are vegetable and which are animal. . . . It is not necessary to go far afield to find subjects for this kind of work; probably what is most wanted is an exhaustive study of the commonest things about us. . . . You may find plenty of work if even you confine yourself to such common things as caterpillars. Lyonet . . . spent many years over his caterpillar, and the result was a monograph which will last for all time."

Objects almost innumerable, other than those included in this book, common, beautiful, interesting, are easily procurable and merit investigation. Make the experiment, and you will see what a good and admirable thing a microscope is. The writer wishes the reader every success in the use of the delectable instrument.

CHAPTER XII

SYNOPSIS OF THE PRECEDING CHAPTERS

** Plants and Animals invisible, or barely visible, to the unaided vision (I).

**Aquatic Plants useful to the microscopist; all visible to the unaided vision (II).

I

Plants and animals usually invisible, unless in large numbers.

* Plainly an animal (*A*).
* Plainly a plant (*B*).
* Doubtfully a plant or an animal (*C*).

A. Body worm-like (*a*).

A. Body not worm-like (*b*).

B. Green, blue-green, brown, sometimes almost black (*f*).

B. Brown; colorless, when dead and empty; single plants not filamentous, but often united to form a ribbon; hard, variously marked, lined, pitted or dotted; motile, or adherent, or stalked. *Diatoms.*

C. Visible to the naked eye (*g*).

C. Not, or barely, visible (*h*).

a. With clustered lateral bristles, or foot-spines, or both or none; body entirely smooth or entirely ciliated. *Worms.*

a. With two anterior and two posterior, spinous legs; eyes and brown mandibles conspicuous. *Chironomus larva.*

b. Legs numerous; free-swimming; in a shell or not. *Entomostraca* and *Phyllopoda.*

b. Legs 8, long, actively motile; body colored. *Water-mites.*

b. Legs 8, short, not active; body elongated, colorless, bear-like. *Water-bear.*

b. Legs none (*c*).

c. With cilia or flagella or both (*d*).

c. Without conspicuous cilia; posterior end of body forked; head and neck distinct; back convex, armed with spines, prickles, scales or tubercles; lower flat surface ciliated. *Chætonotus.*

c. Without cilia; green or brown; one end attached, the free end with several motile and extensile arms. *Hydra.*

c. Without cilia; slowly motile; in a shell of sand, or of membrane, or in a stalked, latticed capsule; usually colorless; motile by protrusions of the body-substance (pseudopods); or only unprotected jelly-like protoplasm. *Rhizopods.*

d. Internal jaws (mastax) present. *Rotifera.*

d. Internal jaws none (*e*).

e. Not visible to the naked eye; actively motile; usually colorless, or variously colored; free-swimming, attached, or in a sheath (lorica). *Infusoria.*

e. Not visible to the naked eye; often in colonies in a jelly mass; often in brown, attached, irregular tubules. *Polyzoa.*

e. Visible to the naked eye; often in a colony in a jelly-mass; often in brown, attached, irregular tubules. *Polyzoa.*

f. Green; a revolving, floating, translucent globe, barely visible to the naked eye; the surface studded with green points, each with two cilia not easily seen. *Volvox.*

f. Green; always freely floating; not stalked; cell-wall not brittle, often punctate, finely striate, or otherwise ornamented; often united to form a ribbon. *Desmids.*

f. Green, blue-green, at times almost black; in soft, cloud-like masses, or a thick, scum-like floating mat; single plant filamentous, sometimes forming a net. *Algæ.*

f. Green; a sub-spherical grain, without rootlets; often collected in a scum-like layer. *Wolffia.*

g. Often in a colony in a jelly-mass; often in brown, attached, irregular tubules. *Polyzoa.*

g. Dark brown; flattened, sub-circular or oval; a broad

border of small hexagonal cells; margin with or without hooks. *Statoblasts.*

h. Green; a revolving, floating, translucent globe, dotted with minute points, each with two cilia not easily seen. *Volvox.*

h. Dark brown; flattened, sub-circular or oval; a broad border of small hexagonal cells; margin with or without hooks. *Statoblasts.*

h. Golden brown; colorless when dead and empty; hard, glass-like, brittle; variously marked, pitted, dotted, or sculptured; motile, or adherent, or stalked; often united to form a ribbon. *Diatoms.*

II

Aquatic plants useful to the microscopist; all visible to the naked eye.

1. Plant submerged (*A*).
1. Plant or its leaves floating (*B*).

A. Leaves in capillary divisions (*a*).
A. Leaves not in capillary divisions (*c*).
B. Leaves floating (*e*).
B. Plant floating (*f*).
a. Leaves bearing small utricles or bladders. *Utricularia.*
a. Leaves without utricles (*b*).
b. Leaf divisions harsh, rigid. *Ceratophyllum.*
b. Leaf divisions soft, flexible; leaves whorled. *Myriophyllum.*
b. Leaf divisions soft, flexible; leaves alternate. *Ranunculus.*
c. Leaf-cells containing a spiral fiber. *Sphagnum.*
c. Leaf-cells without spiral fiber (*d*).
d. Leaves oval, oblong, in threes or fours around the stem. *Elodea.*
d. Leaves long, narrow, ribbon-like. *Vallisneria.*
e. Leaf-stem round; leaves five to nine inches wide, orbicular. *Castalia.*

e. Leaf-stem half-round, often rising above the water. *Nymphæa.*

f. Plant small, disc-like; rootlets several. *Spirodela.*

f. Plant small, disc-like; rootlet one only. *Lemna.*

f. Plant not disc-like, but with spreading divisions (*g*).

f. Plant not disc-like, not divided (*h*).

g. Rootlets none. *Riccia.*

h. Rootlets many, purple. *Riccia.*

h. Rootlets none; single plant a sub-spherical grain; often forming a floating scum. *Wolffia.*

GLOSSARY

Acute: sharp or pointed.
Acuminate: sharp pointed, tapering.
Algal: of or pertaining to the Algæ.
Alimentary: pertaining to food.
Amorphous: having no regular structure nor definite form.
Annular: ring-like.
Antenna (plural *antennæ*)*:* a jointed, movable tentacle or feeler on the head of certain Crustacea and insects.
Anterior: front, going before.
Aquatic: living or growing in water.
Arborescent: branched like a tree.
Assimilated: turned to its own substance by digestion.

Bacilliform: like bacilli, rod-like.
Beak: the lengthened end or front.
Bi: in compound words meaning two.
Eifid: two-parted.
Bosses: knobs, protuberances, usually rounded.
Branchial: relating to gills or branchiæ.

Campanulate: bell-shape.
Capillary: like a hair.
Capsule: an enclosing membrane, covering, or structure.
Carapace: the firm shell or lorica of some Infusoria, Rotifera, etc.
Carnivorous: flesh-eating.
Caudal: pertaining to the tail.
Cellular: formed of or possessing cells.
Cephalic: pertaining to the head.

Cervical: upon or pertaining to the neck.
Chlorophyl: the green coloring matter of plants.
Chitin, Chitinous: the hard, horny substance of the covering of insects and Crustacea.
Cloaca: that part of the intestine in which the intestinal, ovarian and urinary outlets terminate.
Cœcum (plural *cœca*): a part of the intestinal tube.
Colony: a cluster of several or many.
Commensal: sharing the food of their host.
Comminution: the act of pulverizing or grinding.
Component: composing; an elementary part.
Concave: hollow like a bowl.
Conical: cone-shaped.
Conjunction: union, association.
Constricted: suddenly narrowed or contracted.
Contractile: capable of being shortened or drawn together.
Cordate: heart-shaped.
Cornea: the transparent membrane forming the front of the eye.
Corona: the anterior, ciliated region of certain Rotifera.
Crenate: scalloped or with rounded teeth.
Crescent: shaped like the new moon.
Crystalline: resembling crystal; clear; transparent.
Cuticle: the thin membrane covering the surface of plants; the outermost layer of the skin of animals
Cyclosis: the movement of protoplasm within a closed cell.
Cylindrical: like a cylinder or a long, circular body of uniform diameter.
Cyst: a membranous sac or vesicle.

Dentate: toothed.
Denticulate: with small, pointed teeth.
Depressed: flattened from above downward.
Diagnose: to distinguish or determine one from another.
Diagonal: extending obliquely.
Diatomist: a student of the Diatoms.
Diffused: spread out, extended.
Disintegrated: reduced to minute parts.

Distal: the part furthest from the center; remote from the place of attachment.
Diverging: spreading from a central point.
Dorsal: pertaining to the back.
Dorsum: the back.

Ejected: thrown out.
Elliptical: oval.
Emarginate: notched.
Encysted: enclosed in a sac or cyst.
Epithelium: the membrane lining or covering various internal cavities, and free surfaces of animals.
Expansile: capable of being expanded or widened.
Extensile: capable of being lengthened or extended.

Facet: a little surface or face.
Fascicle: a cluster.
Filament: a thread or resembling a thread.
Fission: division or cleaving.
Flagellum (plural *flagella*)*:* a little lash; a long, vibrating thread.
Flexible: capable of being bent without breaking.
Frond: the entire plant of *Lemna, Riccia, Wolffia.*
Frontal: pertaining to the front.
Frustule: the entire Diatom, consisting of two *valves* and the *hoop.*
Fundus: the further end or part of a hollow body; the part at a distance from the entrance.
Furcate: forked.

Gelatinous: like jelly or gelatine.
Globule: a small spherical particle.
Granular: formed of or resembling small grains.
Granules: small grains.

Hemispherical: half a sphere.
Hexagon: a figure with six sides and angles.
Hispid: rough with short, stiff hairs.

Homogeneous: of the same kind throughout.
Hyaline: glass-like, transparent.

Illoricate: without a lorica.
Imbricated: overlapping like shingles on a roof.
Invested: clothed, covered.

Labrum: a part of the mouth of Crustacea and insects.
Lanceolate: lance-shape.
Larva (plural *larvæ*): an insect in its first stage after leaving the egg.
Laterally: by the sides.
Linear: long, narrow, like a line.
Lophophore: the disc supporting the tentacles in the Polyzoa.
Lorica (plural *loricæ*): the sheath or dwelling of certain microscopic animals.
Loricate: with a lorica.

Mastax: the internal jaws of the Rotifera.
Median: middle.
Membranous: formed of a thin skin or membrane.
Mobile: with ease or freedom of motion; moved from one place to another.
Motile: having spontaneous motion.
Monograph: a treatise on a single subject.
Micron: $\frac{1}{25000}$ inch; the unit of microscopical measurement, represented by the Greek letter μ.
μ: the symbol for micron.
Myopic: near sighted.

Nodule: a small, rounded elevation.
Nucleated: having a nucleus.
Nucleus: (plural *nuclei*): a small, solid body of varied form, embedded within the protoplasm of the cell, and the center of its vital activities.

Oblong: longer than broad.

Obtuse: blunt.

Ocular: an eye-piece.

Œsophagus: the tubular passage extending from the pharynx, or throat, to the stomach.

Opaque: not transparent.

Orbicular: circular in outline or nearly so.

Ovary: the organ in which the eggs of animals originate, or the hollow case in plants that encloses the young seeds.

Oviduct: the passage that conducts the egg from the ovary.

Ovoid: egg-shaped in outline.

Papilla (plural *papillæ*): a small, rounded protuberance.

Parasite: a hanger-on, as one animal or plant living at the expense of another.

Parietal: pertaining to the wall or side.

Pedicle: a stem or foot-stalk.

Pellet: a little ball or mass.

Pellucid: perfectly clear and transparent.

Pendant: suspended, hanging.

Perianth: the leaves of a flower that cannot be distinguished into a calyx and a corolla.

Petiole: the leaf-stalk.

Pigment: coloring matter.

Podal: pertaining to, or used as feet.

Polyp: a radiate animal, without locomotor organs, with retractile tentacles around the mouth, and a hollow body, in which are suspended the digestive and other organs.

Posterior: the rear end.

Prehensile: adapted for grasping or seizing.

Preoral: before, or leading to the mouth.

Process: a part prolonged or projecting beyond other parts connected with it.

Protoplasm: the semifluid, colorless, jelly-like contents of animal or vegetable cells.

Protrusible: capable of being thrust forward.

Pulsating: throbbing, beating.

Punctate: dotted with depressions like minute punctures.

Raphides: needle-shaped plant crystals.
Recurved: directed backward.
Refracting: bending from a direct course.
Renal: pertaining to the kidneys.
Reniform: kidney-shaped.
Reticulated: with the form of a net.
Retina: the nerve-coating at the back of the eye.
Retort: a chemist's vessel, usually of glass.
Retractile: capable of being drawn back or into the body.
Rhombic: like a rhomb; diamond-shaped.
Rudimental: imperfectly developed or formed, immature.

Sarcode: the soft, gelatinous matter that forms the basis of the animal body.
Sacciform: sac-like or sac-form.
Sculptured: having raised or incised marks on the surface.
Segment: one of the rings or component parts of a worm or other body.
Semi: in compound words, meaning half.
Serrate, serrated: toothed like a saw.
Sessile: close to the stem, without a petiole.
Shaft: the stem or straight part between the ends.
Sigmoid: curved like the letter S.
Silicious: resembling or formed of silica.
Sinus: an indentation, narrow groove or cavity.
Sphæraphides: spherical clusters of plant crystals.
Spherical: round like a ball.
Spinous: bearing spines.
Spiral: winding like a screw.
Spore: the minute seed of flowerless plants.
Statoblast: the winter egg of the Polyzoa.
Stellate: star-shaped.
Stria (plural *striæ*): fine, thread-like lines.
Stoma (plural *stomata*): a breathing-pore of a plant.
Sub: in compound words, meaning under or less than.
Submerged: under water.
Sulcation: a groove or furrow.

Tortuous: winding, twisting.
Translucent: semi-transparent.
Trophi: the hard parts or chitinous jaws in the mastax of the Rotifera.
Truncate: as if cut off square.
Tubercle: a small, knob-like elevation.
Tubular: resembling or formed of a tube.

Undulate: having a wavy or a ridged surface.
Utricle: a little sack or bladder.

Ventral: pertaining to the lower surface, or *ventrum;* opposed to *dorsal.*
Villous: velvety with soft, short hair-like projections.
Viscera: the intestines, or the abdominal contents.
Visor: the fore-piece of a cap.
Vortical: whirling, rotatory.

Whorl: several opposite leaves around the stem.

Zooid: a small, imperfect animal; one of an animal colony.
Zoophyte: a plant-like animal; a word applied to certain plant-like animals.

INDEX